



Image 78: View into a hot laboratory. Technician Dan Gardner examines irradiated materials using remotely controlled manipulator arms from behind protective walls and shielded windows. (NASA CS-22201)



Image 79: The hot laboratory's safe workarea. Operators are using manipulator arms to work with irradiated experiments in the cells. The hot lab also contained an office, manipulator repair shop, and a decontamination room that connected this "clean" operating area with the radioactive area behind the cells. (NASA C-2003-839)



Image 80: A health-physics technician uses a hand-held “cutie pie” radiation detector to check equipment for contamination. These detectors allowed technicians to quickly monitor specific areas or equipment. They worked in conjunction with the permanent systems that constantly monitored radiation levels throughout the facility. (NASA C-2003-840)



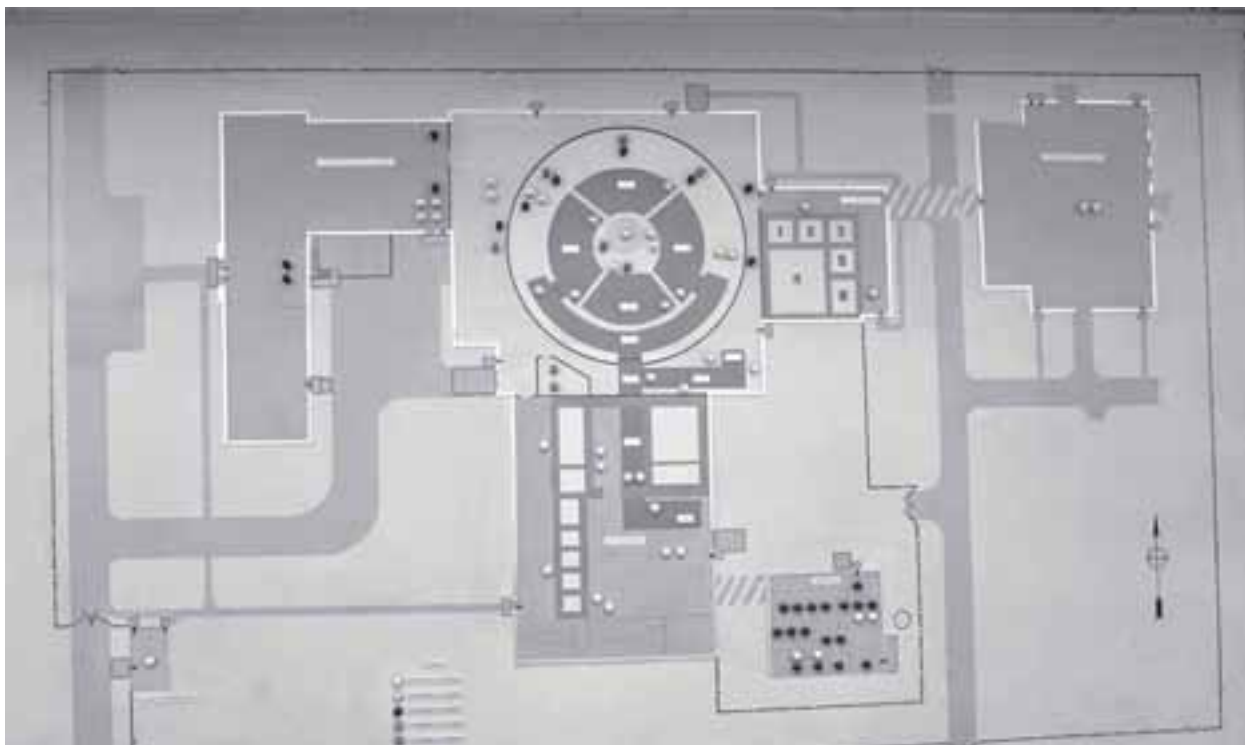


Image 81: Identical Remote Area Monitoring System (RAMS) detector location panels, found in both the health-safety operations office and the reactor control room, and other monitoring equipment allowed operators to monitor radiation sensors located throughout the facility and to scram the reactor instantly if necessary. The color of the indicator lights corresponds with the elevation of the detectors in the various buildings. The reactor could also shut itself down automatically if monitors detected any sudden irregularities. (2001) (NASA C-2001-01150)



Image 82: A Plum Brook technician wearing protective clothing and a mask washes contaminated clothing. The clothing was worn again after it was decontaminated and laundered. The wash water had to be treated as radioactive waste. (2001) (NASA C-2003-841)

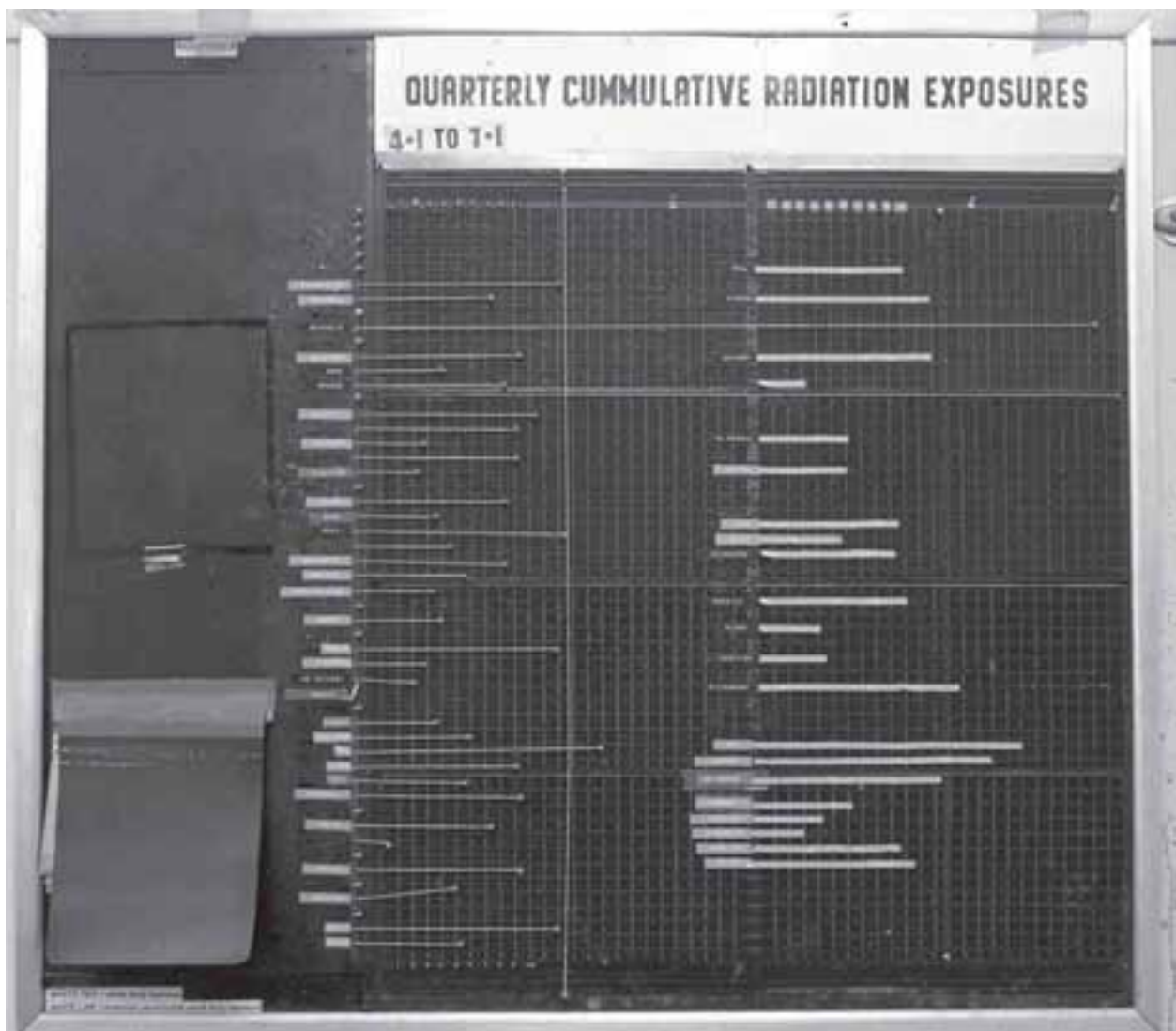
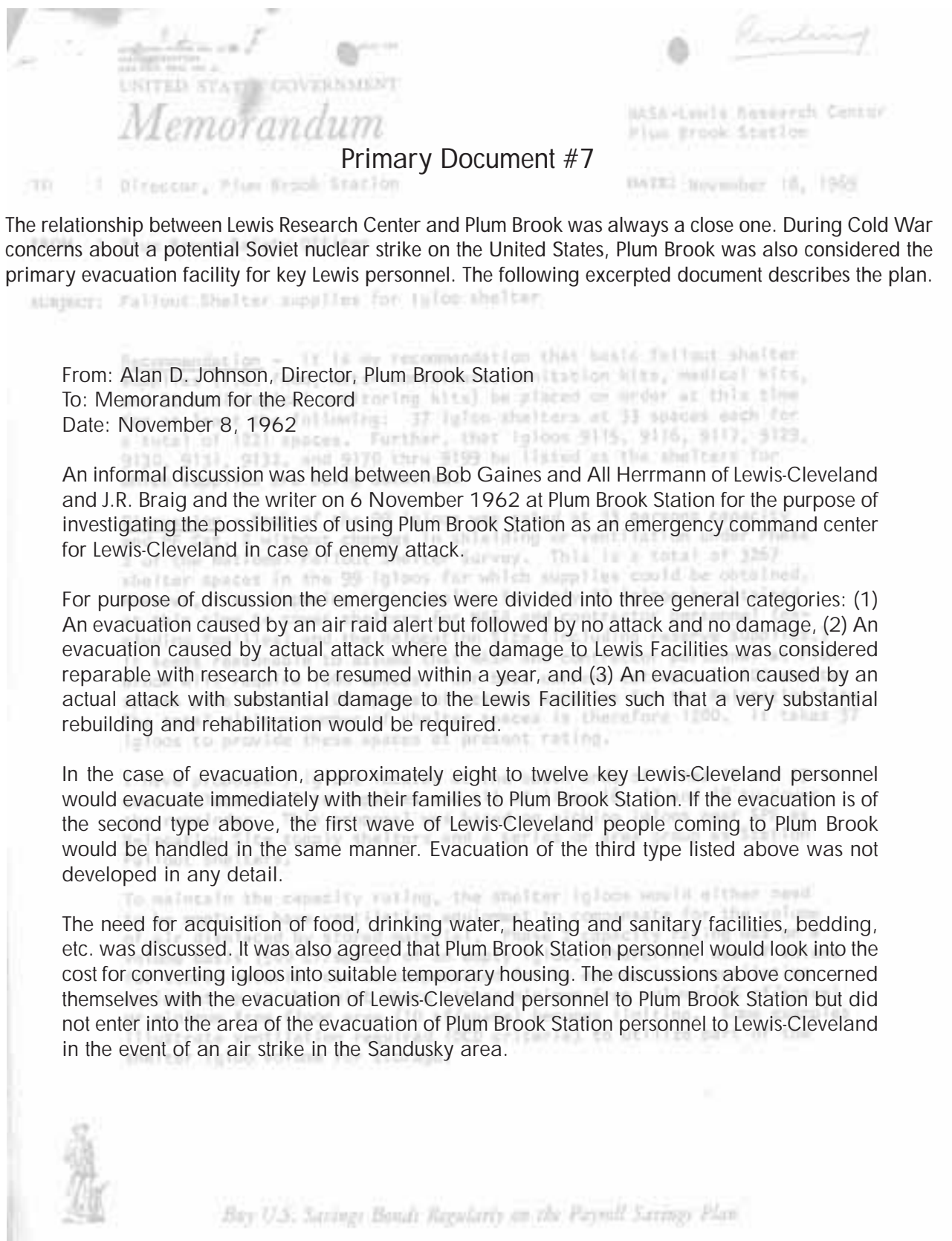


Image 83: This board in the health-safety operations office was updated by health-physicists with data from daily pocket ionization dosimeters and other monitoring instruments to ensure that no one exceeded the legally permissible radiation exposure limits. Strict limits were imposed on the amount of radiation that employees could be exposed to over time. These limits were far below the levels that were considered to cause health risks. All personnel assigned to Plum Brook Reactor Facility were monitored for radiation exposure on a continuing basis by utilizing film badge dosimetry. The frequency of the individual readouts varied from monthly to quarterly depending on the job assignment. Since there was an inherent delay in this technology, it became necessary to have current daily estimates of exposure for personnel who routinely entered radiation areas. Lifetime exposure levels were also closely monitored through regular bioassay samples. (NASA C-2001-01153)





Image 84: Librarians manage files and books in the reactor library. Massive amounts of documentation were required to maintain licensing by the AEC. Unfortunately, many of these documents, including the experiment logs, photographs, and sponsor names, were destroyed. (1961) (NASA C-1961-56372)



The relationship between Lewis Research Center and Plum Brook was always a close one. During Cold War concerns about a potential Soviet nuclear strike on the United States, Plum Brook was also considered the primary evacuation facility for key Lewis personnel. The following excerpted document describes the plan.

subject: Fallout Shelter supplies for igloo shelter

From: Alan D. Johnson, Director, Plum Brook Station
To: Memorandum for the Record
Date: November 8, 1962

An informal discussion was held between Bob Gaines and Al Herrmann of Lewis-Cleveland and J.R. Braig and the writer on 6 November 1962 at Plum Brook Station for the purpose of investigating the possibilities of using Plum Brook Station as an emergency command center for Lewis-Cleveland in case of enemy attack.

For purpose of discussion the emergencies were divided into three general categories: (1) An evacuation caused by an air raid alert but followed by no attack and no damage, (2) An evacuation caused by actual attack where the damage to Lewis Facilities was considered reparable with research to be resumed within a year, and (3) An evacuation caused by an actual attack with substantial damage to the Lewis Facilities such that a very substantial rebuilding and rehabilitation would be required.

In the case of evacuation, approximately eight to twelve key Lewis-Cleveland personnel would evacuate immediately with their families to Plum Brook Station. If the evacuation is of the second type above, the first wave of Lewis-Cleveland people coming to Plum Brook would be handled in the same manner. Evacuation of the third type listed above was not developed in any detail.

The need for acquisition of food, drinking water, heating and sanitary facilities, bedding, etc. was discussed. It was also agreed that Plum Brook Station personnel would look into the cost for converting igloos into suitable temporary housing. The discussions above concerned themselves with the evacuation of Lewis-Cleveland personnel to Plum Brook Station but did not enter into the area of the evacuation of Plum Brook Station personnel to Lewis-Cleveland in the event of an air strike in the Sandusky area.



NASA
Plum Brook Station

Sandusky, Ohio
November 8, 1962

MEMORANDUM for the Record

Subject: Emergency Evacuation of Lewis-Cleveland Personnel to Plum Brook Station

1. An informal discussion was held between Bob Gaines and Al Herrmann of Lewis-Cleveland and J. E. Bragg and the writer on 6 November 1962 at Plum Brook Station for the purpose of investigating the possibilities of using Plum Brook Station as an emergency "command center" for Lewis-Cleveland in case of enemy attack.

2. For purposes of discussion the emergencies were divided into three general categories: (1) An evacuation caused by an air raid alert but followed by no attack and no damage. (2) An evacuation caused by actual attack where the damage to the Lewis facilities was considered reparable with research to be resumed within a year, and (3) An evacuation caused by an actual attack with substantial damage to the Lewis facilities such that a very substantial rebuilding and rehabilitation would be required.

3. It was estimated by Mr. Herrmann and Mr. Gaines that in the case of evacuation of type 1 above that approximately eight to twelve key Lewis-Cleveland personnel would evacuate immediately with their families to Plum Brook Station. Using a median number of ten with an average of four per family it was Plum Brook's opinion that these people could be housed in the homes of Plum Brook Station personnel and that office space could be provided using existing facilities.

4. If the evacuation is of the second type above, the first wave of Lewis-Cleveland people coming to Plum Brook would be handled in the same manner as above. The numbers of people would be the same. It was estimated that the second wave might bring the total number of Lewis-Cleveland personnel to approximately thirty-five. Office space for these people can be provided through use of current facilities but it appears unlikely that housing would be immediately available with Plum Brook Station families. Temporary housing should be provided at Plum Brook Station. No estimate was made for what would be the third wave and it is assumed that these numbers will be developed in the future.

5. Evacuation of the third type listed above was not developed in any detail however it is assumed that the first and second waves of type 2 should be provided for. In all of the discussions it was necessary to make some assumptions as to the availability of Plum Brook Station facilities and personnel. It is the opinion of the writer that if the utilities are still available at Plum Brook Station after such an emergency that some research would continue. If however, the utilities are not available, task of setting up be required if all required. It was communications on services. It was personnel relation

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led to the estimate of thirty-five

drinking water, heating and sanitary was also agreed that Plum Brook Station using igloos into suitable temporary Plum Brook personnel will attempt to implement and supplies that would be at and second waves.

elves with the evacuation of Lewis-Cleveland did not enter into the area of the Lewis-Cleveland in the event of an personnel will look into this and elapsed.

Alan D. Johnson
Alan D. Johnson
Director, Plum Brook Station



The Plum Brook Reactor Opens Its Doors

In an era of both paranoia and enthusiasm about the power of nuclear research, Plum Brook employees frequently held open houses for government officials, the media, high school students, and local families. The following photographic section illustrates some of these events.



Image 85: NASA Administrator James Webb (left) and Lewis Director Abe Silverstein (center, with glasses) peer into the reactor tank while visiting Plum Brook. (NASA C-1961-58735)



Image 86: Congressman Charles Mosher, a longtime Plum Brook supporter in Congress, and Ross Braig (center) are given a tour of the facility by Assistant Director Dr. John C. Evvard. (1961) (NASA C-1961-56466)





Image 87: Bill Kortier uses a sketch of the reactor facility on the blackboard and an aerial photograph of Plum Brook Station to familiarize reporters attending the March 1961 Media Day with the reactor operations just prior to the reactor going critical. Declassified information about the reactor facility was often supplied to the press. (1961) (NASA C-1961-56465)



Image 88: Reporters with cameras in hand are given a tour of the hot laboratory. (1961) (NASA C-1961-56468)



Image 89: Frequent tours were given to high school students and families from the local community to promote an interest in nuclear science and to dispel the anxiety people may have had about living next door to a nuclear reactor. (1962) (NASA PS62-1783)



Image 90: A Plum Brook representative explains the Plum Brook Reactor Facility to high school students. This model of the reactor building and the hot laboratory was intricately designed, down to the smallest detail—moveable manipulator arms, sliding canal doors, and even a blue light in the core. The model hung in the foyer of the reactor office and laboratory building during the reactor's operational days and is still on display at Plum Brook Station. (1964) (NASA C-1964-73677)



The Experimental Program

The Plum Brook reactor became an important tool for gathering the necessary data to construct a safe and efficient nuclear rocket and to design reactors to produce electrical power in space.⁴⁸ Scientists and engineers derived this data by developing an extensive experimental program. There were four basic types of experiments: nuclear rocket experiments, energy conversion experiments, basic radiation effects studies, and basic physics experiments. These experiments consisted of irradiating variously sized and shaped materials, components, and devices to determine how their behavior changed while being irradiated. After irradiation, through analysis in the hot laboratories, scientists examined how their physical properties had changed. The experiments did not always originate with NASA; they were frequently sponsored by outside contractors. The largest sponsors were Lockheed, Westinghouse, and General Electric, though these industrial organizations were carrying out the work on government contracts. They used Plum Brook to investigate the relationship

between cryogenic temperatures and radiation, research the best materials for the NERVA and SNAP programs, and understand the behavior of thermionic diodes and fuel elements during and after irradiation (thermionics is the conversion of heat into electricity). In total, the Plum Brook reactor staff managed eighty-nine experiments during its years of operation.

One of the features that made the Plum Brook reactor unique was its cryogenic facilities. Nuclear rockets needed to not only maintain structural integrity in a radioactive environment, but also withstand the intense cold of both space and the liquid hydrogen propellant. Plum Brook installed special refrigeration capabilities that enabled experimenters to subject materials to radiation and cold at the same time. The first of these experiments was the Lockheed Cryogenic Experiment (62-01),⁴⁹ which determined how various metals reacted to cryogenic temperatures while in a radioactive environment.



Image 92: Hap Johnson (left) and H. Brock Barkley (right) examine a test specimen. It was designed to be inserted into the aluminum “rabbit,” standing on end with its cap next to it. The rabbits housed the sample test materials. (c. 1970) (NASA C-2003-843)

A new \$1 million cryogenic facility was built for the NERVA Components Irradiation experiment (62-16), and was about twenty times larger than the one used in the Lockheed Cryogenic Experiment. It had a twenty-kilowatt low-temperature helium refrigerator that could maintain a temperature between -409 and -39 degrees Fahrenheit. For the other extreme in temperatures, materials could also be irradiated at $+3272$ degrees Fahrenheit while in the reactor. It could test larger instrumentation components such as accelerometers, strain gauges, and displacement transducers, as well as smaller mechanical components like control drum assemblies, dynamic bearings, and molybdenum instrumentation tubes.⁵⁰ This was a unique capa-

bility at Plum Brook; few other nuclear facilities could run similar tests.⁵¹

Along with Lockheed, Westinghouse also played an important role in the NERVA program. The Westinghouse Astronuclear Laboratory was responsible for the nuclear reactor designed to go into the rocket, and the Plum Brook facilities were essential in helping Westinghouse scientists understand which materials were best suited for a radioactive environment. The Westinghouse NERVA Experiment (63-05) was a test to irradiate materials, especially transducers, for the nuclear rocket. The materials were placed in water-cooled capsules in the Plum Brook HT-1 facility. Samples



Image 93: The experiment control room, located directly below the reactor control room, contained various monitoring equipment. In this photo, Johnny Miller examines the Experiment Data Logging and Alarm System, which recorded all events during the operating cycles of the Plum Brook reactor in minute detail. Earl Boitel, seated, checks data input sources. (1964) (NASA P64-0713)

included instruments as well as complete component assemblies.⁵² This experiment lasted for over three years. Westinghouse Refractory Fuel Compounds (62-15) was the first fueled experiment at the reactor, run in August 1964. The fueled experiment enabled irradiation of materials at high temperatures and high power for long periods of time. The ability to test fueled experiments was one of the major reasons that the Plum Brook reactor was constructed.

NERVA was not the only nuclear space initiative researched at Plum Brook. SNAP represented another significant application of nuclear power.

It was hoped that the results from these experiments would help engineers design better circuits and other electrical equipment that could operate reliably and withstand the radioactive environment of a space reactor. Nuclear Electric Sub-Systems and Component Irradiation (63-09) explored the reaction of electronic equipment to neutron and gamma radiation for the SNAP-8 program. Radiation damage occurred every time that radiation interacted with matter. This phenomenon was explored in 1946 by Eugene Wigner; it became known as “The Wigner Effect.”⁵³ What made this problem more difficult was that the damage occurred to the materials before any direct visual



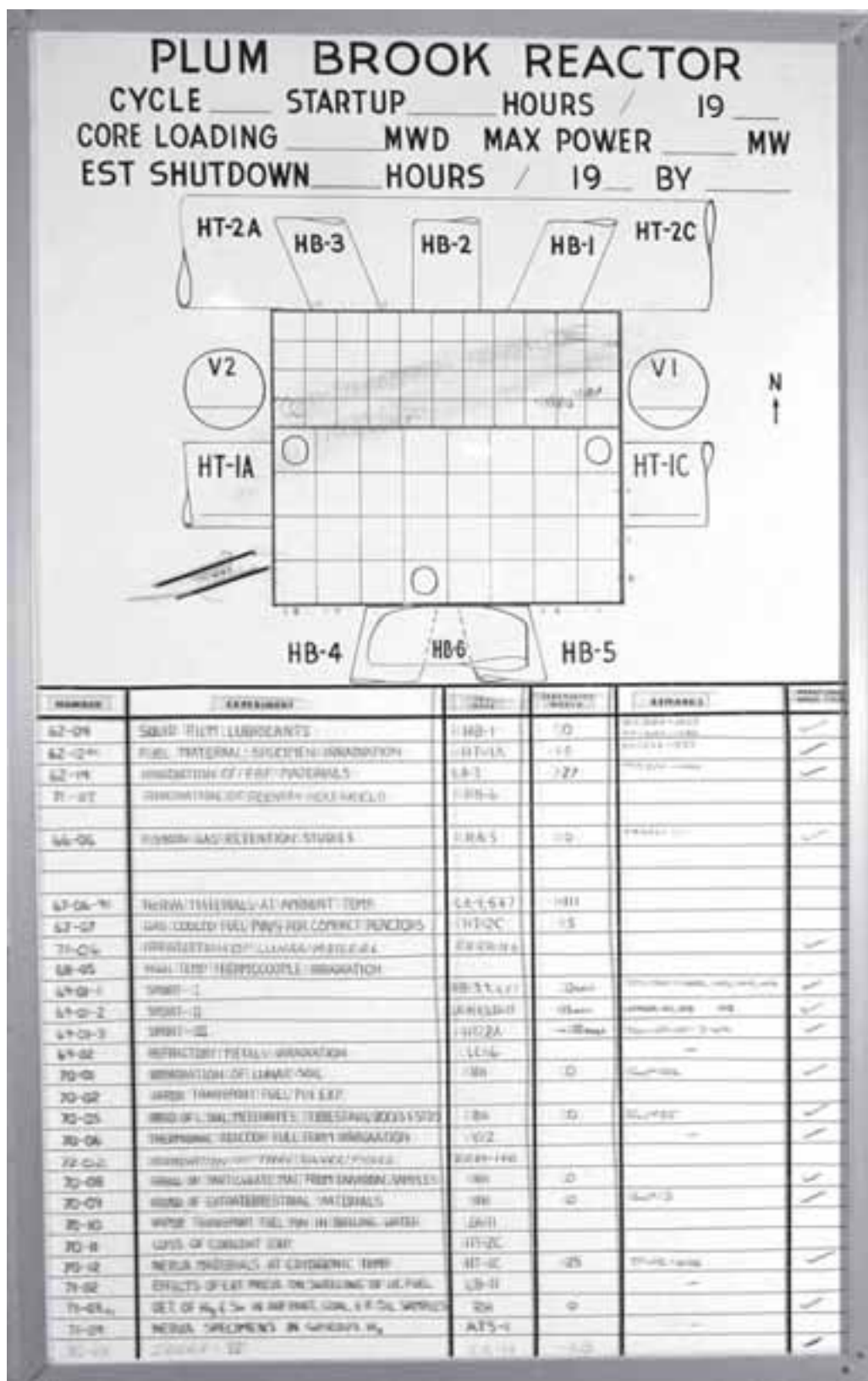


Image 94: This chart hung in the reactor building outside the experiment control room. It listed the experiments to be irradiated for each cycle and the through-holes, or access ports, to the reactor assigned to them. The core diagram also showed where the experiment was to be placed. The three circles in the lower portion of the grid represented the pneumatic rabbit facilities. (2001) (NASA C-2001-1258)

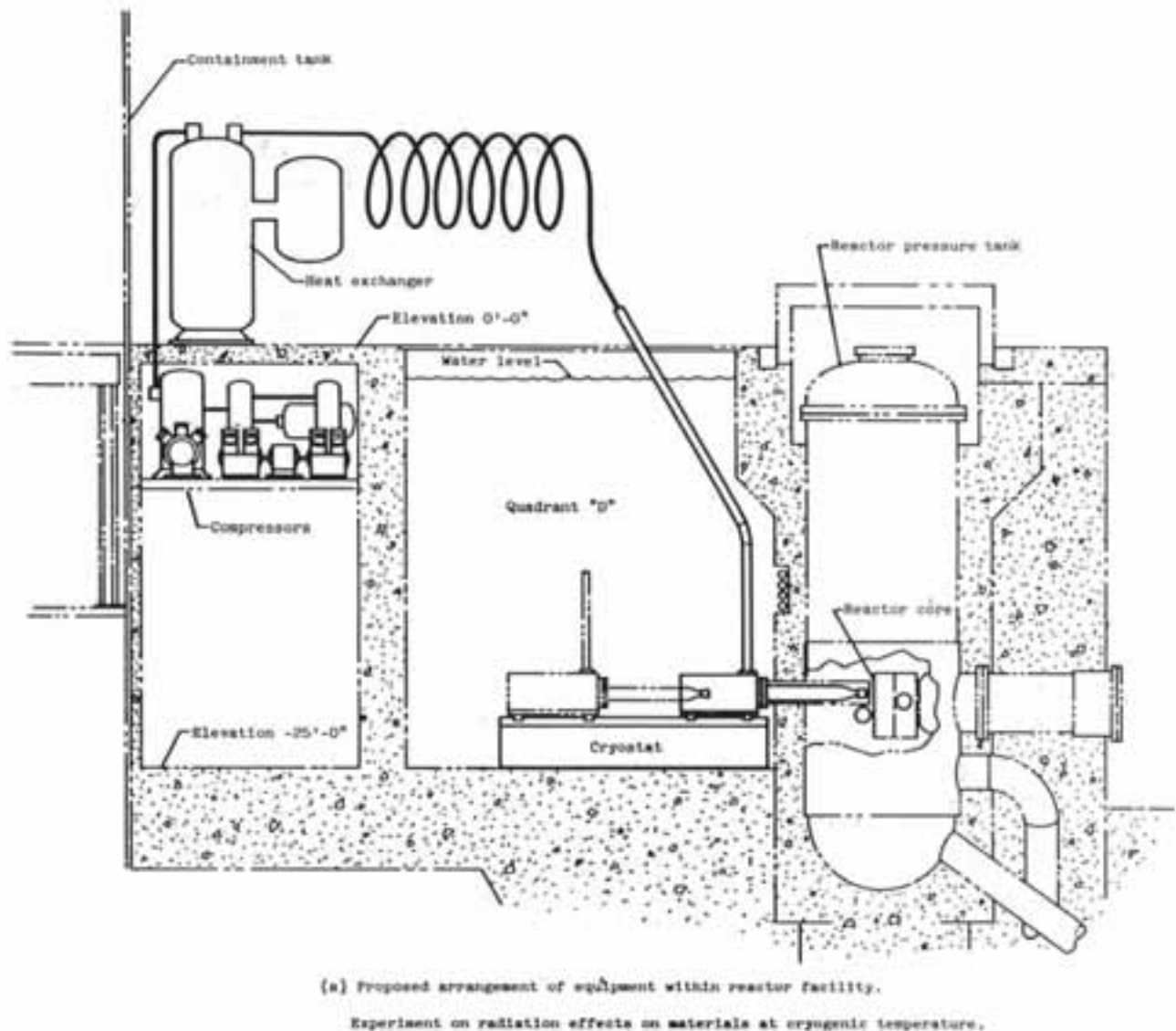


Image 95: The HB-2 Cryogenic Experiment investigated the effects of low temperature and high radiation on various metals for potential use in space vehicles. The experiment consisted of a refrigeration system, a transfer system, and devices for measuring the strain resulting from radiation and temperature extremes. Four cryostats (or test loops) were used to measure tensile-fatigue compression. Each cryostat was six inches in diameter and nine feet long. One could be set up on the floor of Quadrant D, inserted into the core through the HB-2 beam port, and transferred remotely to the hot cave on the outside of the quadrant for removal of the specimen. (NASA CS-18942)





Image 96: Laboratory technician Allen Larkins (upper right) and engineer David Willinger (lower left) working in the metallurgical laboratory of the Plum Brook reactor. (1961) (NASA C-1961-55641)



Image 97: Lockheed-Martin engineers make adjustments to the cryostat refrigeration machine that was being prepared for use in the Plum Brook Reactor Facility. The machine was used to test metals for their cryogenic resistant qualities. (January 1962) (Cleveland Public Library Photograph Collection, Ohio, Sandusky, Industry, NASA, Plum Brook Station)



Image 98: Astronaut Gordon Bean gets ready to insert the plutonium-238 heat source into the Space Nuclear Auxiliary Program 2 (SNAP-2) thermoelectric generator. Apollo 12 was the first mission to use the generators. This generator was capable of producing seventy-three watts of power for the Apollo lunar surface experiment package and had a lifespan of eight years. (1969) (NASA AS12-46-6790)



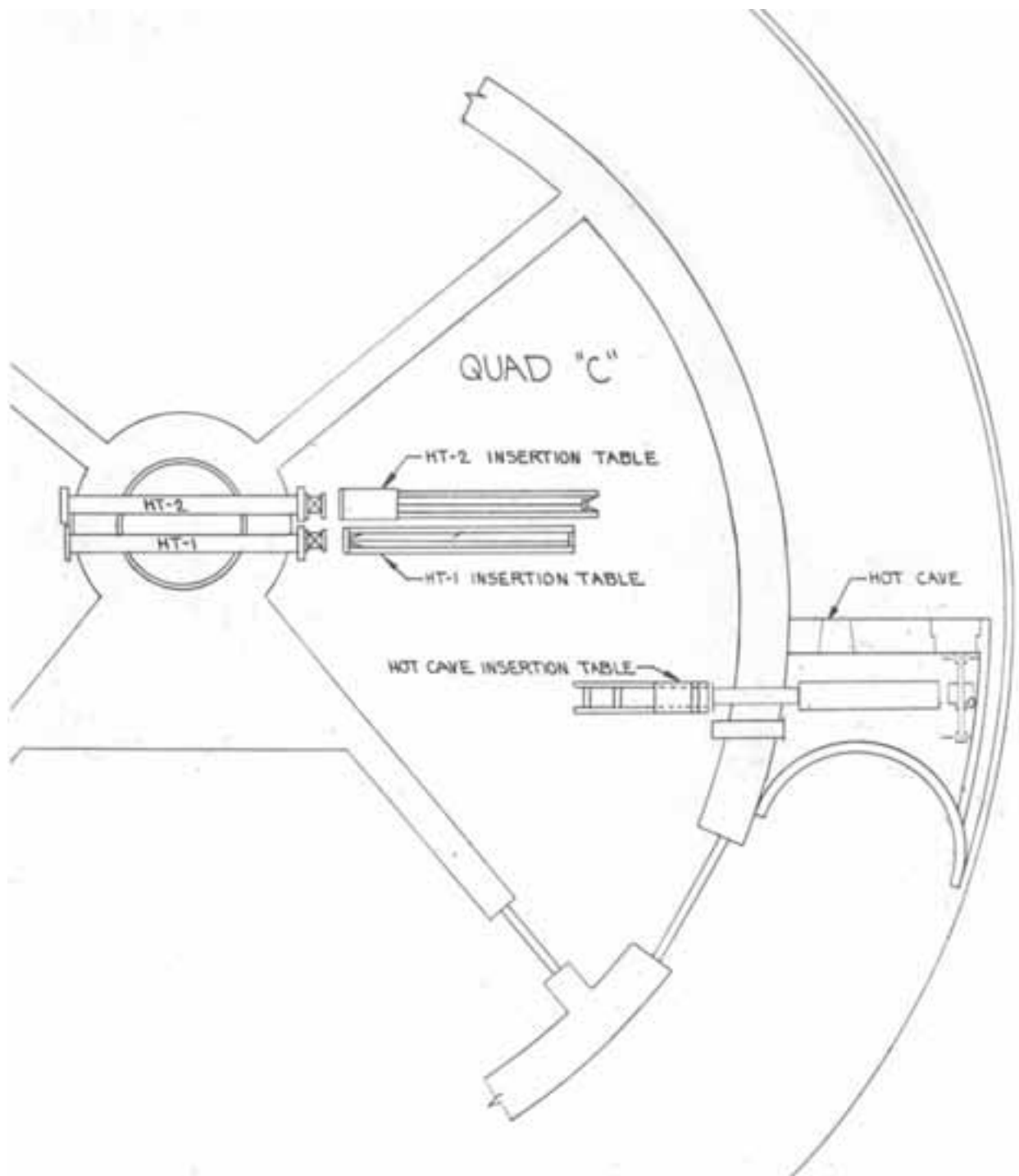


Image 99: Diagram of two insertion tables in Quadrant C. Experiments were loaded here and sent through the two horizontal through-holes or ports (HT-1 and HT-2) into the reactor core to be exposed to radiation. After irradiation, they were removed and maneuvered through the canals to the hot lab for analysis. (1965) (NASA PS65-1136)

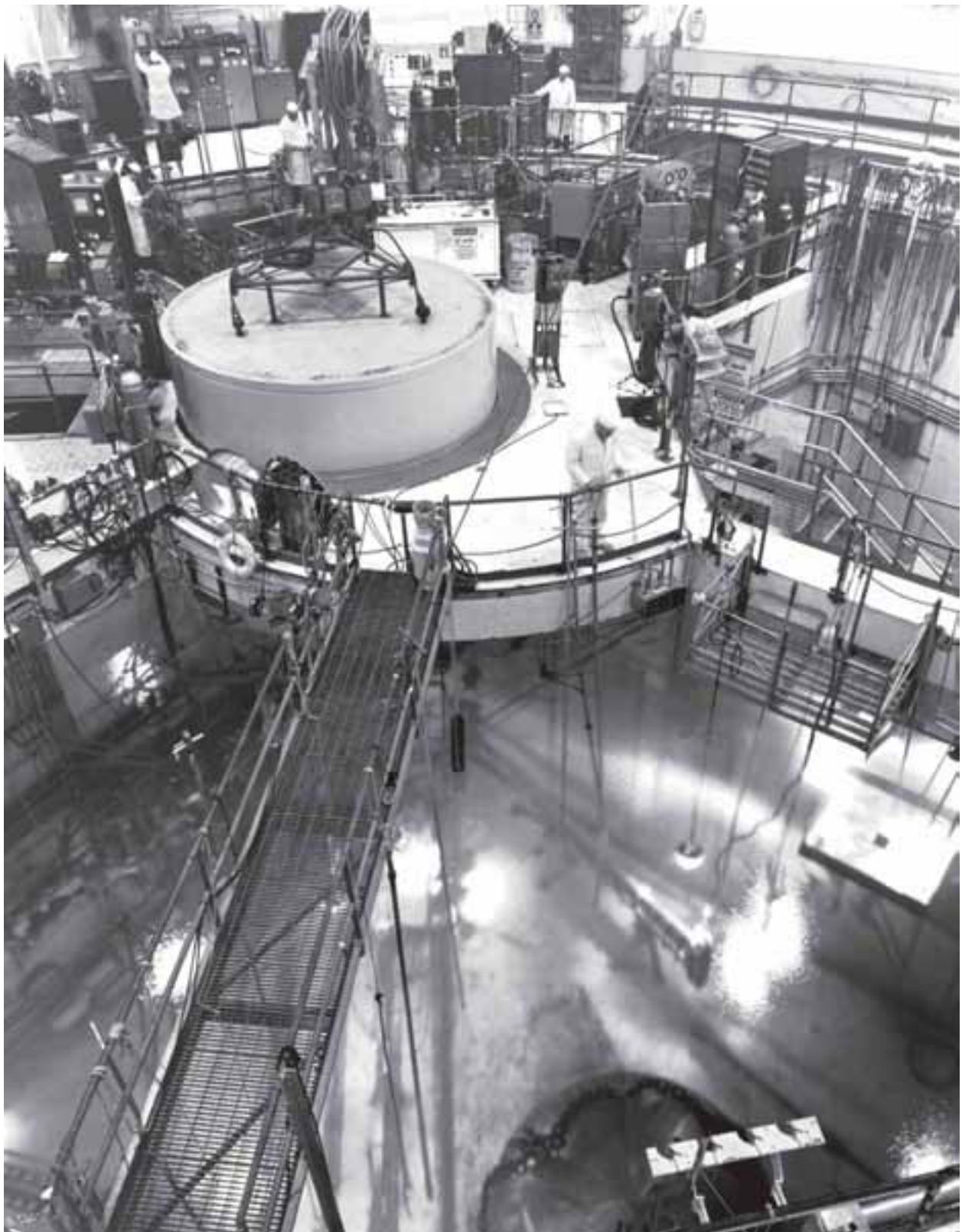


Image 100: The technician on the walkway is operating the hydraulic cranes, which insert and remove the experiment facility (seen in the bottom of the quadrant) into the core via Horizontal Through Hole 1 (HT-1). Experiment 62-12, a setup to evaluate the fuel and fission product retention qualities of tungsten-uranium dioxide dispersions (the dispersions were fission heated to anticipate the operating temperatures of rocket fuel elements), was permanently installed in Quadrant A. (NASA C-2003-827)



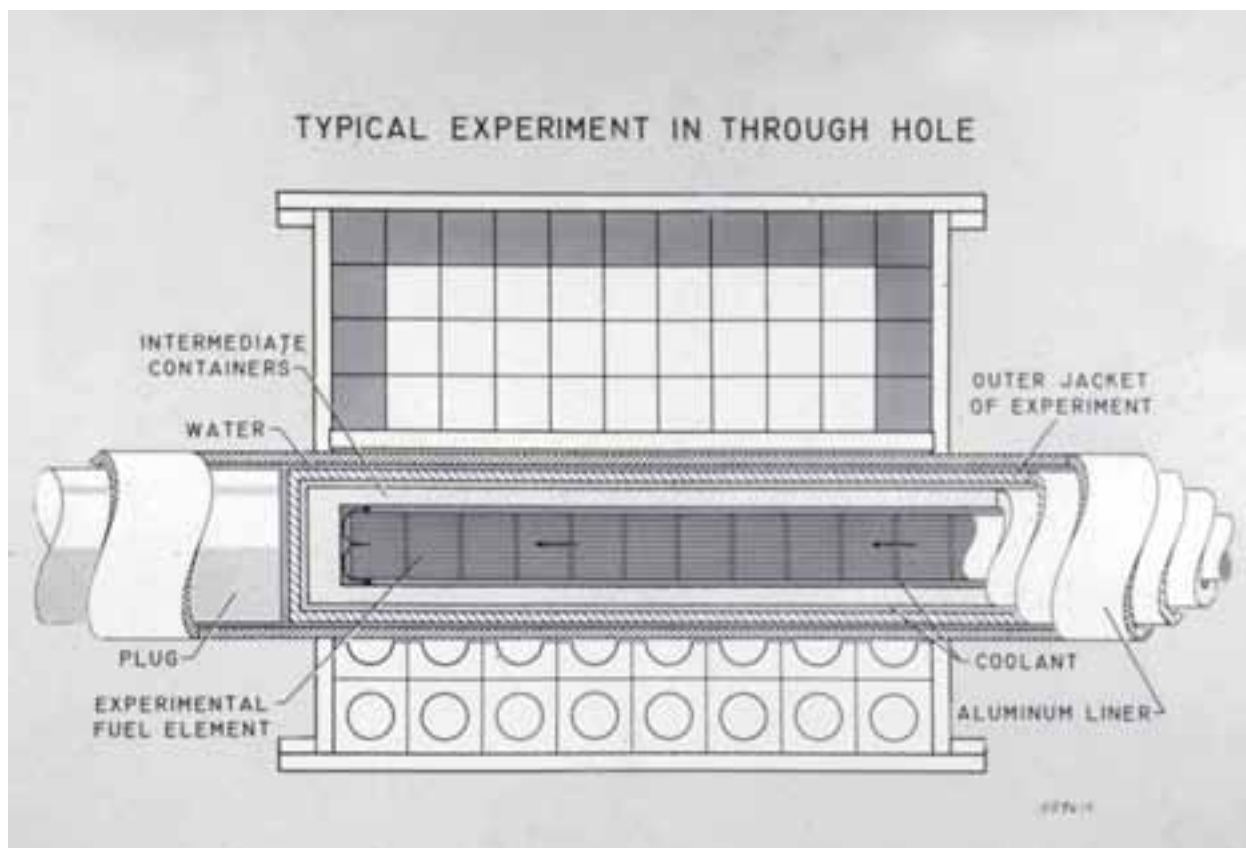


Image 101: Diagram of an experiment after it was inserted into HT-1. The fuel element is surrounded by coolant, water, several containment layers, and an outer jacket. A plug fills the test hole behind the experiment. HT-2 ran parallel to HT-1. (NASA CS-13591)

observations could be made. This experiment electrically energized the components during irradiation and special test circuits monitored their behavior and charted a graph comparing operation time versus radiation dosage received.⁵⁴

To make the SNAP program more effective, scientists had to better understand the science of thermionics, or the conversion of heat into electricity. George Grover, from Los Alamos, initiated the first investigations that showed the possibility of thermionics. Plum Brook's first testing in this area was the Thermionic Diode Experiment (63-03), which attempted to demonstrate the feasibility of fission conversion. This conversion promised to be of great significance for space applications, because if it worked, the heat from the reactor could be used to power onboard electrical components. The experiment was placed in a vertical beam hole tube (VT-1). General Electric, through its Special Purpose Nuclear Systems

Operation, sponsored a related experiment.⁵⁵ Funding for the project came from General Electric, along with support from NASA, the AEC, the Office of Nuclear Research (ONR), and the Advanced Research Projects Agency (ARPA). The experiment was a long-term test of cylindrical diodes to be used in nuclear thermionic power systems. The performance of the diodes was monitored during irradiation in the Plum Brook reactor, and then the diodes were examined at the Vallecitos Atomic Laboratory or in the Plum Brook hot laboratory.⁵⁶

One of the most difficult problems that arose during the Plum Brook experimental program was quantifying how important its data was to the scientific community. These experiments were all considered basic research, meaning that the primary mission was simply to better understand how materials responded to a radioactive environment. It is often difficult to objectively measure

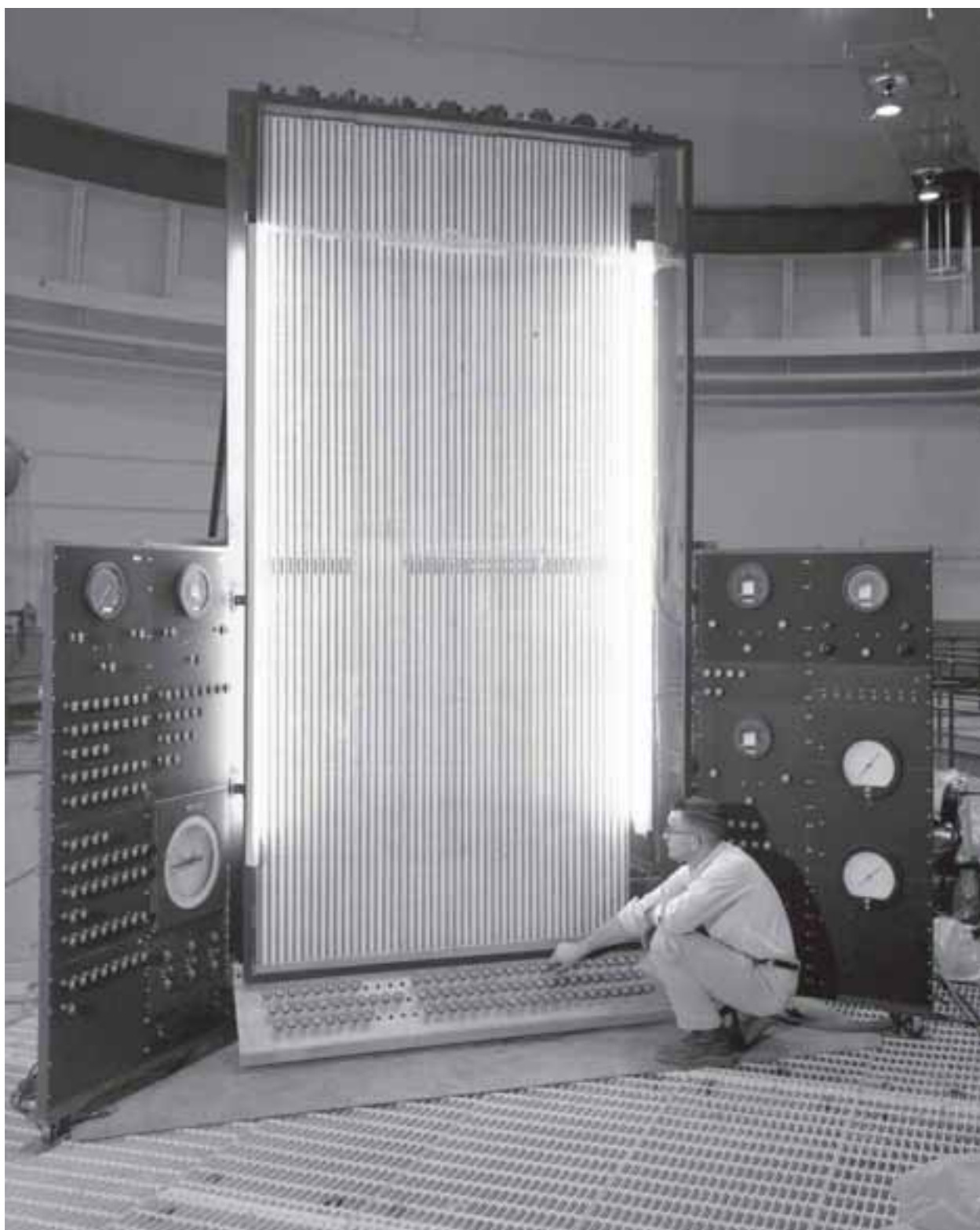


Image 102: John Hire adjusts an instrument console for final hydraulic testing prior to the reactor going critical for the first time. The console was on the lily pad area at the center of the quadrants, directly above the reactor pressure tank. (1960) (NASA C-1960-55125)





Image 103: Technicians wheel a large “thimble” containing experiments for irradiation into the containment vessel through the truck door. When the reactor was shut down and the protection of the containment barrier could be broken, this door was the only way large items of equipment and hardware could be taken in or out of the containment vessel, utilizing fork lifts if necessary. (1961) (NASA C-1961-55811)



Image 104: Technicians work inside the thimble. (NASA C-1961-55810)



Image 105: Hap Johnson (left) and Brock Barkley (right) examine test specimens from an experimental run in the Plum Brook reactor. (NASA C-2004-741)

just how valuable and practical such research will turn out to be in the short term. However, the information gained from the Plum Brook reactor occasionally resulted in significant findings with immediate results. For example, during the Westinghouse NERVA Experiment in 1964, the reactor irradiated pressure transducers that were to be used for an upcoming full-scale reactor test in Nevada. During the early radiations the transducers failed, which was a complete surprise to the Westinghouse operators. This outcome forced them to develop new transducers for the test. Barkley said, “It’s obvious how much more effective, economic, and important it was that the problems were detected in this reactor rather than waiting for the loss of the transducers to invalidate an extremely expensive and important full-scale NERVA reactor test.”⁵⁷

Nevertheless, a controversy over the importance of some of the reactor research developed. Not everyone believed that the data it was returning was valid. One engineer, speaking anonymously in a recent interview, said that he believed at the time that measurements taken from the cryogenic experiments had no statistical meaning. Even today, he questions the significance of the data. This engineer argued that while the cryogenic temperatures changed the physical properties of the materials, the radiation from the reactor itself had little, if any, measurable effect. He maintained that the same results would have been obtained if the materials were placed in cold storage alone, without any reactor present. Barkley was aware of this controversy and agreed that during the early years of the reactor, Plum Brook researchers were still struggling to determine how to best construct experiments to return significant





Image 106: Puncture rig. Puncture rigs were used to penetrate the outer capsule of each experiment and measure the pressure increase in the system due to released gases during irradiation. The plastic vial on the left was used to determine the isotope content of fission product gases, xenon and krypton, using gamma ray spectrometry; the tubular sample container below it was used to measure the volume percent of the two gases. The entire puncture operation and collection of gas samples was done inside the hot cells using the remote manipulators. The sample containers were then removed from the puncture rig and transferred to the radiochemistry laboratory for analysis. (NASA P69-3224)

data. By 1967, he felt confident enough to proclaim, "We now know how to obtain valid test data."⁵⁸ One year later, in a congratulatory report to his employees, Barkley said, "Plum Brook has the facilities and competence and is well on the road to becoming the standard for the industry in the field of radiation effects."⁵⁹

In addition to the radiation damage studies on materials and nuclear fuels, the reactor rabbit facilities were used to support experimental programs for other government agencies using neutron activation analysis. These irradiations included jet fuel to determine trace element content in compliance with the Clean Air Act of 1970 (PL88-206). Corn and other grains were irradiated

for the Department of Agriculture to determine trace element content, and analyses of fuels (such as crude oil, coal, and fly ash from coal-fired power plants) were performed on over 1,000 samples per year from 1971 to 1972 for the Environmental Protection Agency (EPA) (70-08). Dean W. Sheibley wrote, "This work is significant because it demonstrates that [instrumental neutron activation analysis] is a useful analytic tool for monitoring trace... elements related to environmental protection."⁶⁰ The research was also significant because it began proving that the work at the Plum Brook test reactor could extend beyond space applications.

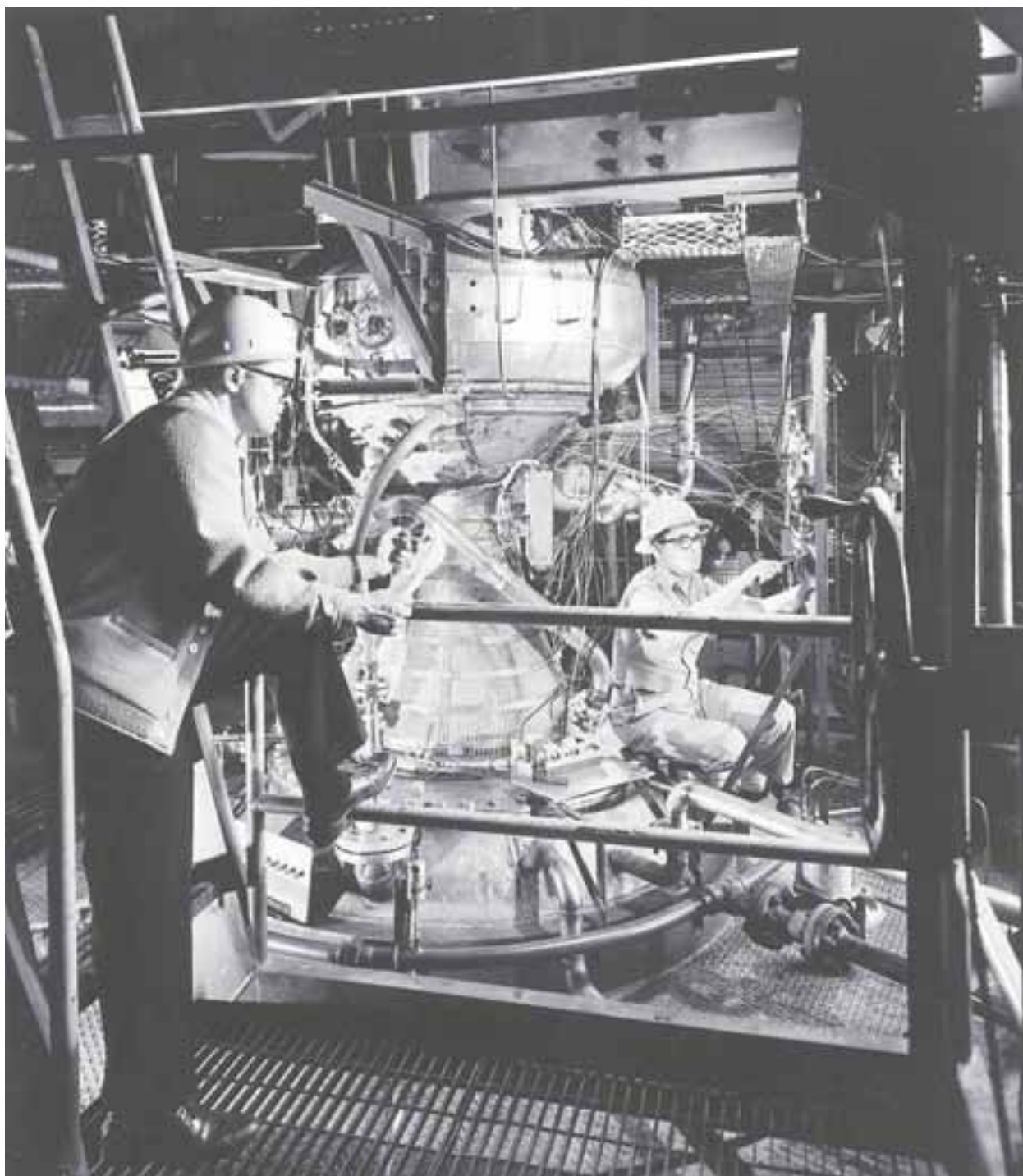


Image 107: NERVA engines are bolted to a vacuum test chamber in Plum Brook's B-2 facility. The test will help ensure that the engines will be able to start without an auxiliary power source. The B-2 facility was—and still is—the only place on Earth that can fire a full-scale engine and subject it to simulated harsh and demanding conditions of the space environment. The physical features of the B-2 facility are impressive. It has a huge stainless steel chamber thirty-eight feet in diameter and fifty-five feet tall. It can simulate the cold of space (–320 degrees Fahrenheit) with its liquid-nitrogen-cooled walls, and mimic the heat of the sun with its quartz lamp thermal simulators. Plum Brook engineers needed to maintain a vacuum, similar to space, in the B-2 chamber at the same time that the engines were firing and the test rocket was expelling hot gas. The answer was the development of speed ejectors, which were able to keep up with the exhaust output of the engines so that every cubic foot of gas was immediately removed from the chamber. Taken together, these features enabled engineers to simulate all the conditions of space, except zero gravity. (Cleveland Public Library Photograph Collection, Ohio, Sandusky, Industry, NASA, Plum Brook Station)



Plum Brook Station Test Facilities

Besides the reactor, other facilities at Plum Brook during the 1960s began making important contributions to the space program.



Image 108: The Hypersonic Tunnel Facility was capable of creating air velocities and temperatures that simulated flight speeds of seven times the speed of sound, at an altitude of 120,000 feet. (1969) (NASA C-1969-00725)



Image 109: The Cryogenic Propellant Tank Site (K-Site) was a test chamber for liquid hydrogen rocket fuel tanks. (1967) (NASA C-1967-03315)





Image 110: Shake Tower. (1959) (NASA C-1959-51298)



Image 111: The Spacecraft Propulsion Research Facility (B-2) was capable of testing space vehicles, and especially upper stage rockets like the Centaur, in a simulated space environment. The large vacuum test chamber could accommodate vehicles as large as 22 feet in diameter and 50 feet in length. The facility stood 74 feet high and extended 176 feet below ground. (NASA C-1999-00305)





Image 112: The Space Power Facility was the world's largest space environment simulation chamber when it was constructed in the 1960s, and it remains so today. It has a 100-foot diameter and stands 122 feet high. In this chamber, large space-bound hardware and spacecraft, even as large as the International Space Station, can be tested in an environment similar to that it will encounter in space. (1970) (NASA C-1970-03690)

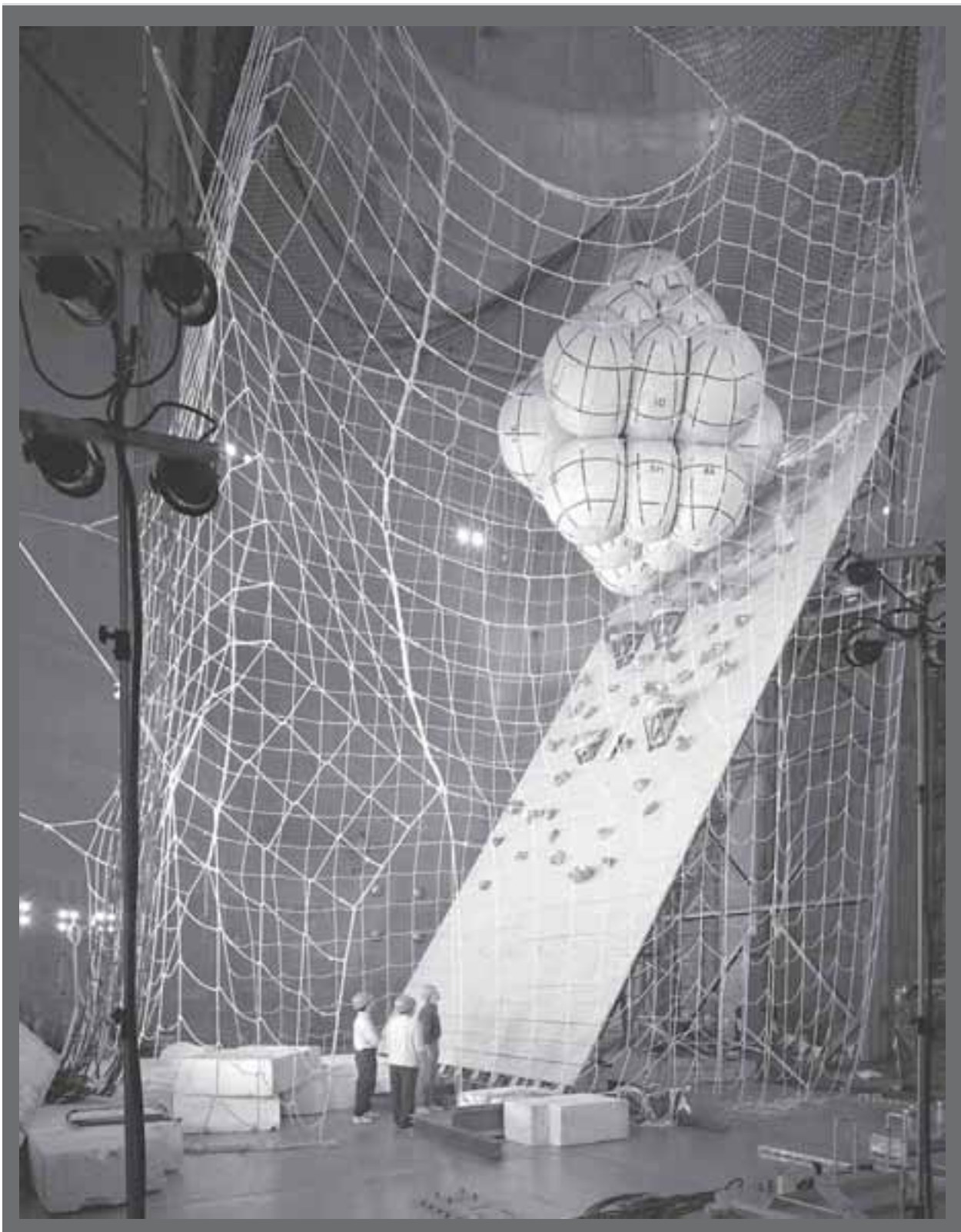


Image 113: In 1995, the airbags for Mars Pathfinder were tested in the Space Power Facility (SPF). (NASA C-1995-01861)



Plum Brook Station Social Activities

There was a great deal of camaraderie and socializing in the Plum Brook community. Employees and their families became close, since many were close in age and background and had all relocated together to the Sandusky area.



Image 114: Plum Brook employees enjoy an impromptu cookout. (NASA C-2003-844)



Images 115 and 116: Plum Brook events included formal dances and Christmas parties. (NASA C-2004-739) (NASA C-2003-845)





Image 117: Employees shared family gatherings like this April 1972 Easter egg hunt. (NASA C-2003-846)



Image 118: Plum Brook Station Manager Hap Johnson endeavored to populate the Plum Brook landscape with trees. The land had largely been cleared during its use for Plum Brook Ordnance Works. Today the station has many wooded areas. (NASA C-2004-740)

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Primary Document #8

In 1970, Robert Earl wrote a science fiction novel called *Hot Lab*, which was about the use of radioactivity as a scientific research tool. It took place at the fictitious Pine Valley Laboratories, where engineer Richard Rendfel, the book's protagonist, moved with his young family. The author was actually Robert Oldrieve, a hot lab manager at Plum Brook. It is uncanny that the fate that Oldrieve chose for his fictitious test reactor happened to the Plum Brook reactor just three years later.

[Describing the hot laboratory]

We get nearly everything you can imagine: bottles of irradiated calf's liver, elastomers, transistors, timing devices, sledge hammer handles, and static eliminators for tape recorders. It seems that everybody wants to irradiate everything they can lay their hands on in hopes of a scientific or commercial breakthrough.

[Realizing that the entire reactor and hot laboratory might be closed]

The place could be shut down, without any great loss in relocation of the entire organization. The remoteness of the area isn't needed anymore. The capital assets aren't irreplaceable. Sure, most of the reactors are twenty years old or older, and the separation plant is no longer needed. I'll bet these technicians aren't paid enough; they came from the country areas, and most probably the plant is located here to take advantage of them! They had previously led simple lives, had few needs, and still require very little.

The final irony of the morning, aside from the fact that Pine Valley engineers could easily find jobs if relocation for them were necessary, is that...the entire Pine Valley Plant could be completely closed down without anyone being the wiser or really caring if it never reopened! It's almost tragic that no one really cares when someone else's job is abolished, not even if the job is an ultimately valuable and still current and required college-trained career.

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Mothballing the Reactor

Despite the growing importance of the Plum Brook reactor's experimental program, it never became the leader in the field of radiation effects that its managers hoped it would. Budgetary cuts by the Nixon administration resulted in its closure before many of its experiments could be completed. The NASA scientists and engineers who suddenly lost their jobs were devastated. They first learned of the plans to shut the reactor down at noon, 5 January 1973, when Bruce Lundin, director of NASA's Lewis Research Center in nearby Cleveland, Ohio, assembled them in the Plum Brook auditorium to talk about the nation's post-Apollo vision for space. This vision included a new initiative called the Space Shuttle, but not a nuclear rocket. NASA's new goals were reusability, projects that promised short-term results, and quick and efficient access to space. The nuclear rocket had none of these attributes. Like the Apollo program, each nuclear rocket could be used only once, and its missions would consist of costly (and, some argued, environmentally dangerous) voyages into

space. Though proponents of the nuclear rocket believed that they were ready to take on a Mars mission with astronauts, neither the budget nor the nuclear incentive remained.

Without a nuclear rocket there was no need for NASA's only large-scale nuclear test reactor. The closure was to be immediate, meaning that very day. The reactor employees were unprepared for this decision. The reactor had just received a new load of fuel elements and was ready to run another several years. In addition, many of the experiments had just commenced when the shutdown announcement came. The stunned and dejected Plum Brook employees returned to their reactor in a somber mood. Hours later the entire shift stood in the control room and watched Don Rhodes and Bill Fecych shut the reactor down for the last time. Plum Brook engineer Earl Boitel recalled, "That was a very traumatic experience. There were a lot of tears in people's eyes."⁶² As they began looking for other jobs, Plum Brook personnel lamented that one of



Image 119: The Apollo 17 crew—Eugene Cernan, Ronald Evans, and Harrison Schmidt—visit Lewis Research Center and have their picture taken with Bruce Lundin. The Apollo 17 astronauts were the last humans to walk on the Moon on 14 December 1972. Just over two weeks later, NASA Lewis Research Center Director Bruce Lundin ordered the closure of the Plum Brook nuclear reactor due to budgetary cuts for long-term space projects. This photograph was taken about five weeks after the Plum Brook reactor shutdown. (16 February 1973) (NASA C-1973-00774)

the most powerful test reactors in the world was not even given the opportunity to complete its last experimental cycle. In an effort to vent their frustration, reactor engineers filled chalkboards once reserved for nuclear research with cartoons of Plum Brook as a sinking ship.

Plum Brook was not alone, as many reactor facilities were forced to close nationwide. The Brookhaven Graphite Research Reactor closed in 1969, the Materials Test Reactor closed in 1970, and a Los Alamos reactor shut down in 1974. The AEC's influence was also in decline. After a 1971 Supreme Court ruling on AEC licensing procedures, the commission was forced to streamline

its organization and procedures. Critics claimed that it was improper for the agency to regulate the very same reactors that it managed. The AEC, which was founded in August 1946, officially suspended operations in October 1974 when President Ford signed the Energy Reorganization Act. The Act placed the AEC's research and development functions under the Energy Research Development Administration and its licensing functions under the Nuclear Regulatory Commission.

The shutdown of the reactor did not mean that the work was complete. The reactor team was given six months to place the facility in standby mode. By 30 June 1973, this carefully executed



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The first time the Plum Brook reactor employees knew that their reactor would be shut down was during the following speech made by Bruce Lundin, the center director at NASA Lewis Research Center. The speech was made at noon on 5 January 1973 at the Plum Brook auditorium. Just a few hours later the reactor was shut down for the last time. The following is an edited and excerpted transcript from an audiotape recording of the event.

PLUM BROOK SHUT DOWN SPEECH

Bruce Lundin

Members of the staff of Plum Brook Station, I've asked that we meet together here at this time to enable me to tell you all that I know and all that I can about what I learned yesterday when I was with Jim Fletcher [NASA Administrator] and George Low [NASA Deputy Administrator] and others in Washington. Our country's current fiscal management and fiscal problems and some of the program actions at NASA will have a very significant effect on all of us. I was anxious to do this at the very earliest possible moment. I'd just like to check this point, I'm required to check that only NASA Lewis civil service personnel are present here in this room. You'll see at the end a little timetable for spreading this information to broader circles than just the Lewis people.

First I'd like to give you just a few words about the total national picture to provide background for you and to put our necessary Lewis actions into some total picture, total context. I'll do this in a sketchy brief way so I can get to matters more important to all of us as quickly as possible.

Jim Fletcher has been working very closely with President Nixon the last few days, and of course with Nixon's staff, the Office of Management and Budget, the staff arm of the president. And from Jim Fletcher's very open and candid remarks to all of us yesterday it became terribly clear. This will be no real surprise from what you've been reading in the newspaper. The President is completely determined to limit federal outlays and expenditures this year to that 250 billion dollar number, to have no new taxes on the people, and to reduce the size of what Nixon refers to as a federal bureaucracy. If after doing all of these things he can have a strong defense establishment, he'd like that too. But the President, and from the actions that Jim Fletcher had observed in Washington, the President is indeed clear that he's going to restrict federal expenditures and have no new taxes.

We don't know the specifics to the different agencies because of the way the President's been running this problem. But Jim Fletcher has touched base with his colleagues in Washington and other agencies, and he got the very clear picture of large wholesale cuts everywhere. And this will be unfolding, of course, during the month and made clear in the President's budget message on or around January 29th. Some entire agencies are disappearing completely. Many of the so-called soft programs or Great Society programs will be gone. And that was the general picture of Nixon's management of the fiscal matters in the country.

As regards NASA now, Jim Fletcher had an understanding and gentleman's agreement with the President that NASA could count on running on what was called his level budget concept, which was somewhat over 3 billion dollars a year. That level budget understanding is now gone. And Fletcher spoke of considerable disappointment that he

had to give up his level budget concept. As regards NASA for the rest of this fiscal year and the impact into fiscal '74, we find that the Shuttle is in and the Apollo-Soyuz link up to the docking with the Russians in space in '75 is in. Those two items are in by Presidential direction. The Viking Program is in the budget. Our launch vehicle activities are secure. Skylab is, of course, going to fly in April so that will be done. Many other programs are disappearing from NASA.

Now as regards Lewis Research Center, NASA finds it has to fit its total program under some, not only reductions in the New Obligation Authority in fiscal '74, but more importantly, even to fit under a very tight cost limit this current fiscal year. To fit under that, NASA management and the Office of Management and Budget, have found it necessary to decide to terminate all research work that cannot be expected to have a needed or useful application, say for a period of, within this decade. Long-range research and development work that cannot be expected to have a real need or application until the 1980s must be terminated at this time and priority given to more shorter range activities in say the 3 to 5 year time span. This means that essentially all nuclear power and nuclear propulsion R&D work will be terminated this fiscal year.

In view of the total national picture, and after seeing this, working with the folks in Washington, I can understand this and can therefore accept the rationale for this decision. It's one I don't agree with, I don't think that it's exactly right to do it just this way, but I can understand it and accept it and that's what all of us have to do now. This means, of course, that the reactor here at Plum Brook will be closed down during the remainder of this current fiscal year. Further, the rest of Plum Brook Station will have to be closed down at the end of fiscal 1974. This, I should emphasize, will be done in a manner in which we leave it in a, what we call a standby or mothball condition. It's not to be abandoned in place and surplused off because all of us in NASA management are confident that many of these very unique and important facilities and people will be coming back to them to do work in them, when the space program reaches the point when they are needed. This will be, of course, a massive and challenging, difficult job. It's about the toughest job in management.

As far as the people go, there will be reductions in force both this fiscal year between now and June 30th and into next fiscal year. For Lewis I can't give you exact numbers because they're not worked out in that kind of detail yet. For Lewis it will mean a reduction in force of around 400 by June 30th, generally 50/50 between here and Cleveland. And another 2 to 300 people by the end of fiscal '74.

You will hear in the days and weeks ahead, quite a bit of talk, you'll be engaged in some of this conversation yourself, you'll certainly read it in the newspapers or hear it on the radio, about a lot of flack going on in Congress. The Congress and the President are in many ways running on a collision course. It's going to be a very active time between the White House and the Hill this spring.

My response to all of this? What happened to me a week or few days ago is the same thing that's happening to you now. You suffer a shock that you can't quite believe it, a feeling of pain and anguish, of course, and you lick your wounds for a day or two. Then you decide that's not very constructive so where do we go from here? We are completely dedicated to at least two things at this point. One is to do a very first-class orderly job of finishing our work here. And secondly we're going to be completely dedicated to finding every one of you that wants a job, a good job someplace. I intend to, Monday, as soon as I can, to call such people as Tom Paine and Harry Finger and



many of my other friends in other agencies in government now that I can tell them what's happening and make your interests and capabilities known to them. We're going to set up here and in Cleveland a real massive outplacement service for you. The fact that you possess unusual skills and capabilities and experience, I've discovered, is known everywhere throughout the country and Washington and there will be interest in a lot of places of making use of your skills and experience if the people have the ability to expand their staffs.

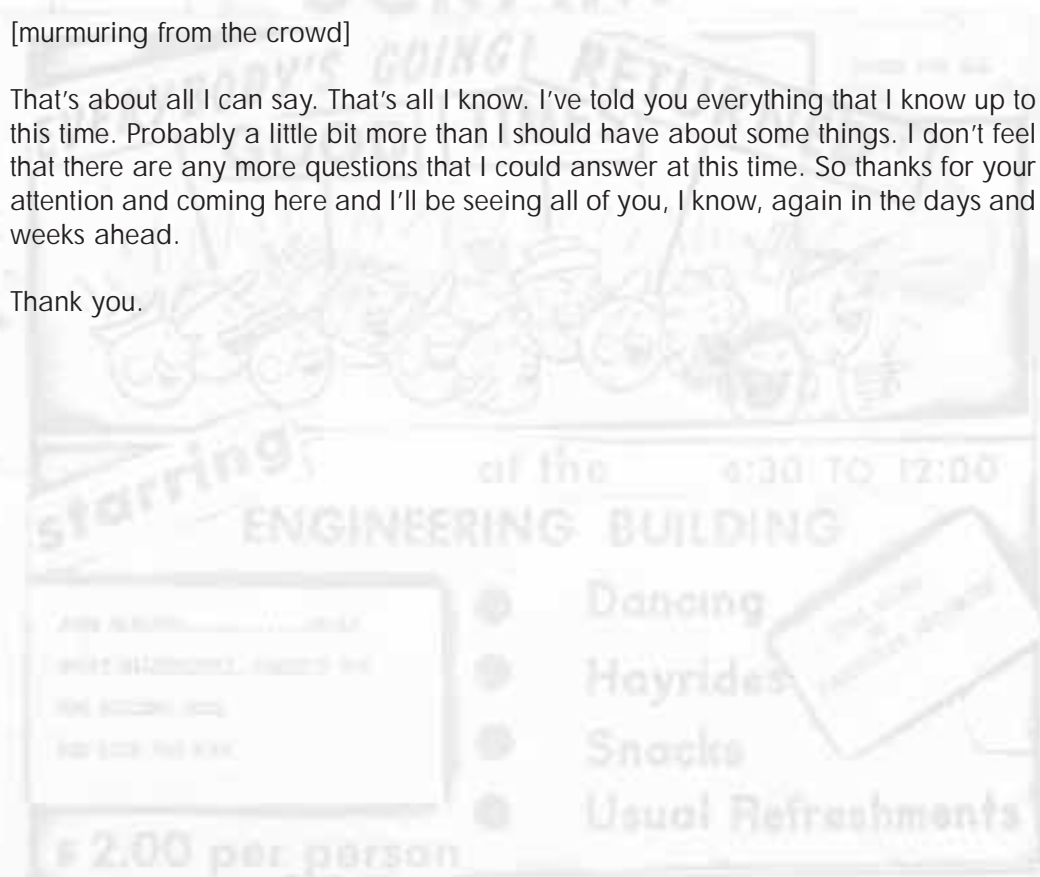
My own sort of philosophical views here now . . . As I think back on all of this I think nuclear reactor power for space really disappeared about four years ago when Tom Paine opted for the shuttle instead of the space station when he was told he could only have one of the two. Plum Brook was really created for a space program that simply didn't materialize at a rate that permits it to be sustained now. The space program simply has slipped downstream in point of time.

I was anxious to tell you the same time that the Congressman Mosher was hearing it. I will be leaving here in a few minutes and going back and telling the folks in Cleveland about this, so you're the first to hear. Contractor management will be informed at 1:00 today but that will be for management information. There will be a press release coming out of Washington and out of here and Cleveland at 4:00 this afternoon. All of this information is restricted to government employees, except for notifying contractor management. At 4:00 a document becomes public in Washington. No doubt when many of you get back to your desk, your phones will start to ring and people will be asking you what was the meeting here for and what's going to happen and so forth. I'll have to ask you to tell them, "We always have meetings but it was nothing of particular concern at this time."

[murmuring from the crowd]

That's about all I can say. That's all I know. I've told you everything that I know up to this time. Probably a little bit more than I should have about some things. I don't feel that there are any more questions that I could answer at this time. So thanks for your attention and coming here and I'll be seeing all of you, I know, again in the days and weeks ahead.

Thank you.



Hobbies, travel beckon retirees...



Michael G. Valente, joined Lewis in 1964 after a 1 1/2 year stint in the U.S. Army. He has been in the Plum Brook Design Section 2 month. George, 50, is a retired Army aviator. He is now in charge of research and testing for Lewis. He and his wife, Mary, have four grown children, two sons, and two daughters.



George, 50, is a retired Army aviator. He is now in charge of research and testing for Lewis. He and his wife, Mary, have four grown children, two sons, and two daughters.



Plum Brook to close

Nuclear propulsion, power projects to phase out



Clyde A. Stone will be in charge of a project director of the Plum Brook Station. He will be in charge of the station for the next 18 months. He will be in charge of the station for the next 18 months. He will be in charge of the station for the next 18 months.



James F. Lewis will be in charge of a project director of the Plum Brook Station. He will be in charge of the station for the next 18 months. He will be in charge of the station for the next 18 months. He will be in charge of the station for the next 18 months.

Director Bruce T. Lundin, announced to employees of the Center in January 2 that the necessity to reduce Federal expenditures during the current fiscal year and beyond has forced a significant reduction in many of NASA's current and planned programs. These reductions affect the expenditures level for the remainder of this fiscal year and planning for fiscal year 1974. In general long range research and technology efforts not expected to be needed for some time in the future will be reduced or terminated. Priority will

be given to more urgently needed (near-term) work.

The impact on Lewis will be the termination of essentially all of the current nuclear propulsion and power programs by the end of this fiscal year. Major facilities not to be utilized in NASA's restructured program will be placed out and placed in standby condition. At the Plum Brook Station, the Reactor Facility will be placed in standby condition by the end of this fiscal year and the remainder of the Station will be closed by the end of Fiscal Year 1974.

The closure of Plum Brook and program terminations at the Lewis Cleveland site will result in the separation of many employees over the next 18 months.

Officials expect a reduction of about 600 Civil Service positions at Cleveland and Plum Brook. About half of these jobs will be eliminated by the end of this fiscal year, the others during FY 1974. This reduction is in addition to the earlier planned reduction of 90 that must be made by the end of FY 1973.

NASA explains cutbacks

NASA has made a number of program reductions to adjust its activities to

current activities. In research activities, NASA has



will be a matter of a few weeks. He will be in charge of the station for the next 18 months. He will be in charge of the station for the next 18 months. He will be in charge of the station for the next 18 months.

Lab mounts massive placement drive

Almost as soon as official notice came of Plum Brook's closing and manpower cutbacks at Lewis-Cleveland, a massive drive got underway "to find a position for everyone affected by the RIF who needs help," says Dr. Bernard Lubansky, Deputy Director, Technology.

At the direction of top management, an Employment Committee was formed

ing Design Division, several Plum Brook divisions and several divisions under the technical services directorate.

"One of the most important factors in the placement efforts has been the strong support of top management. Center Director Bruce T. Lundin has spent long hours contacting companies and arranging for future con-

The first step of the Employment Committee was opening the Outplacement Service Office in the basement of the DEB Annex.

"The office is set up to give all the help we can to the affected employees, but it is not intended to replace their own efforts," he explained.

The Outplacement Service Office activities are broken down into the fol-



Through Director Lundin's efforts

Leading figures seek uses for PB

Lewis is taking action to interest other organizations in the capabilities of its 8000-acre Plum Brook Station.

A major symposium has been organized for leading executives in government, education, business and industry to explore ways in which the nation can best use the facility and personnel. The symposium hosted by Lewis Director Bruce T. Lundin will be held April 23 and 24 at the Plum Brook Station.

It was announced by NASA Headquarters in January that, in order to meet Federal budget targets, the agency had to cut back in several areas of work, personnel and facilities. Plum Brook facilities include a 60-megawatt nuclear research reactor which is one of the most versatile in the nation, and the world's largest environmental simulator which can duplicate and maintain air densities from sea level to the vacuum of space at temperatures rang-



ing from minus 300 degrees Fahrenheit to plus 180 degrees F.

Since the announced closure Director Bruce T. Lundin and other interested Center personnel have been exploring other possible uses for the unique Plum Brook facilities. A strong effort at finding new jobs for the more than 300 highly trained scientists and

Science Foundation, Major Foundations, universities and Ohio State government departments are also represented.

A brochure outlining the capabilities of various facilities at Plum Brook has been prepared and sent to invitees. In his introduction to the brochure Lundin emphasizes creative thinking about the station with some

suggestions of his own. He points out that in addition to the specific facilities, the large open land areas at Plum Brook, which originally were needed for hazardous waste disposal, "now offer attractive potential for other purposes such as noise abatement research, road and railroad test tracks, or perhaps... ground-effects machine development."

ranges interviews, assists employees in establishing contacts with prospective employers, and sends resumes. He is assisted by Robert G. Ragdale. Ragdale can be reached at PAX 8431 or PBX 6409 and 8431 or PBX 409 and Bartle at PAX 8240 and PBX 373.

The final activity under the Outplacement Office is the

concerning job opportunities and to follow the committee's efforts in upcoming issues of the Lewis News. He also stated that volunteer help was needed. Any wishing to help, may

Robert J. Usher of Training Section is coordinating efforts with American Institute of Aeronautics and Astronautics

Aeronautics and Astronautics (photo)

statistics, handling and logistics.

the serving Lewis Plum Brook, p semi-skilled a may be affected have to do it to success of our

Usher said.

Usher employs



- 3 -

You are hereby requested to take all

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5) 503-05-01 Energy Conversion, Generation,
and Transport Research

01 Advanced Nuclear Propulsion
Research

ayton Conversion Technology under

35-01 shall be substantially

- 1 -

12/26/72

(2)

Memo to Director, LeRC

Subject: Termination of Space Nuclear
Power and Propulsion Programs

In accordance with recent budgetary
and programmatic decisions, the following

RTOP's are cancelled:

1) 503-25-01 Thermionic Reactor
Power Technology

2) 503-25-04 Nuclear Power Reactor
Technology

3) 503-25-05 Zirconium-Hydride Reactor
Power Systems Technology

4) 503-25-06 Thermoelectric Power

- 4 -

Please submit a plan
the terminations resulting
cancellations or modi

- 6 -

We regret that these actions must be
taken to cancel these important RTOP's.

These NASA, University,

personnel, who have devoted

portion of their professional

research and technology

nuclear systems, to

accomplishments and

actions are not

of the programs,

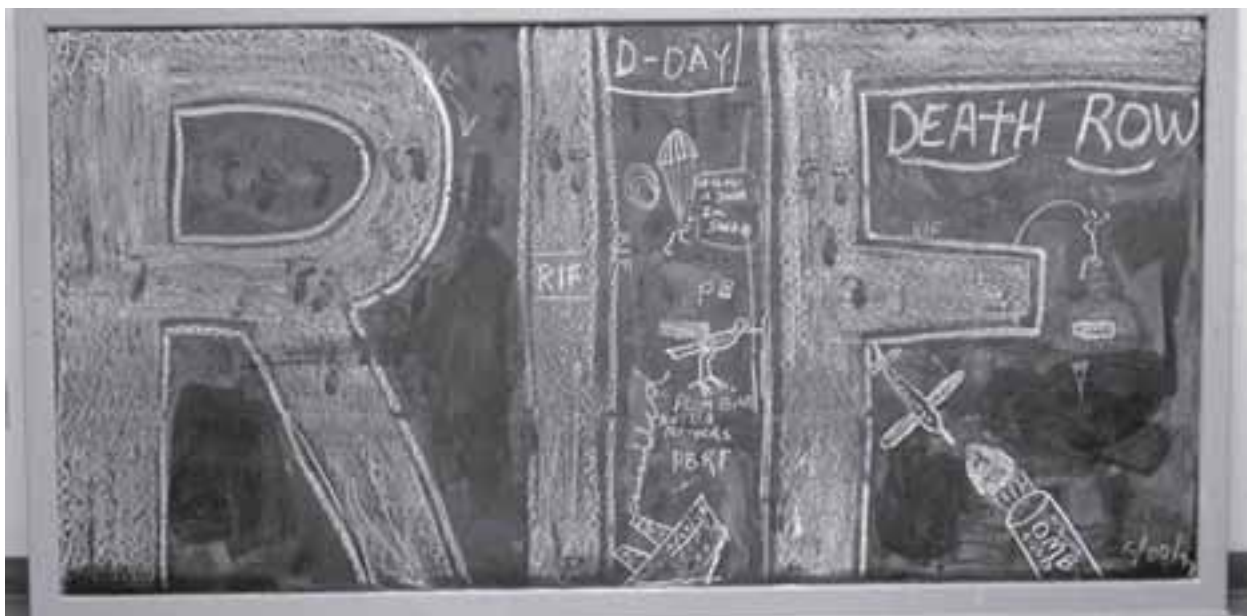


Image 120: This blackboard graffiti expresses the sentiments of Plum Brook employees after learning about the reactor shutdown. It went untouched for over twenty-five years and is now being preserved as a museum artifact. RIF stands for “reduction in force,” which is the standard expression for layoffs at federal facilities. The graffiti was one way in which employees expressed their deep feelings of frustration. Other graffiti includes, “Old reactors never die, they just decay away,” and “Decay in peace.” (2001) (NASA C-2001-01166)



Image 121: Bill Fecych shut down the reactor for the last time on 5 January 1973, as Dale McCutcheon, Dan Gardner, George Gowan, and others looked on. Employees had gathered in the Plum Brook auditorium for an announcement by Lewis Center Director Bruce Lundin, little expecting to hear the news that Plum Brook would be closed. Two hours later, stunned employees crowded into the reactor control room and, just after 2 p.m., witnessed the final shutdown of the Plum Brook reactor. (NASA C-2003-847)





Image 122: Two stacks are felled simultaneously during the decommissioning of the Hanford reactor. In recent years, several other reactors besides Plum Brook have been decommissioned. Successful decommissioning projects include the Watertown Arsenal, Shoreham, the Saxton Nuclear Experimental Corporation, Argonne, Pathfinder, Elk River, Fort St. Vrain, Shippingport Nuclear Power Station, and Trojan. (1977) (Department of Energy Photo 1001138)



Image 123: This calendar, left open in the reactor building just days before the reactor's final closure, has remained untouched for almost 30 years. Despite their disappointment at the shutdown of their facility, Plum Brook employees worked diligently for the next six months to put the reactor into protective safe storage. They hoped that this mothballing procedure would allow the reactor to be reactivated at a future date when research could again be funded. (2001) (NASA C-2001-1182)

“mothballing” procedure was completed. Of the 200 or so Plum Brook reactor employees, the vast majority left NASA. About twenty were sent to Lewis Research Center. Most easily found new work either in other government agencies or in private industry. Their experiences at the Plum Brook reactor gave them valuable skills that were coveted by other organizations. NASA also helped them find new work through elaborate job placement assistance.

The facility was mothballed with such care partly because many of the employees expected that it would reopen again in the near future. Initially, it was thought that the reactor would be used

again if the nation revived the human Mars mission in the 1980s. In the meantime, other possible uses for the reactor and the other facilities at Plum Brook Station were explored. In April 1973, a symposium of over fifty scientists, educators, politicians, and economists was held to explore future uses of the station. Their proposals included an industrial park and a multi-university research center. U.S. Representative Charles Mosher pursued several other options. One plan was to convert the reactor into a power facility, but both the AEC and NASA said that was impossible. Another proposal called for using the reactor at a lower power (six megawatts) for continued neutron activation analysis testing for the EPA (which had already





Image 124: Spurred by the energy crisis, NASA, and the Energy Research and Development Administration (ERDA) installed this large 100-kilowatt wind turbine for alternative energy research at Plum Brook. The 100-foot tower supported two sixty-two-foot blades, which could reach forty rpm in eighteen-mph winds. When the Plum Brook reactor shutdown was announced, Congressman Mosher and others endeavored to find alternative uses for Plum Brook Station. The wind turbine was one of the few successful programs on the station in the 1970s and 1980s. By the late 1980s, several of the testing sites at Plum Brook were reactivated and remain in operation today. (28 September 1976) (NASA C-1976-3906)



Image 125: After its mothballing in 1973, the reactor went silent. It was visited only by the numerous deer in the area and a skeleton crew that continued to monitor the facility during the standby period. (NASA C-1961-55643)

been started with experiment 70-08). Dr. James Blue of the NASA Lewis Research Center's cyclotron facility proposed another use for the reactor. At the time, Blue was working with the Cleveland Clinic treating cancer patients with neutrons from the cyclotron. With a ten-year grant from the National Cancer Institute, he helped treat over 4,000 patients at Lewis. He suggested converting Quadrant B at Plum Brook into a medical facility to use epithermal neutrons to treat patients who had brain tumors called glioblastoma.⁶³ Any decision for future use had to be made before the reactor was to be finally shut down in June 1973. When no decision came about, it became clear that the mothballing procedure was going to be permanent.

During spring 1973 the reactor area was fenced off and locked. The nuclear fuel and wastes were removed, and the still radioactive equipment was placed in the hot laboratories, containment vessel, and canals. The rest of the facility was decontaminated and became subject to NRC licensing. Emergency telephone, water, and electrical systems were retained. The NRC's "possess but do not operate" license required annual renewals, quarterly radiological testing, and regular inspections of alarms and security tools. It also required a staffed communication center, an administrative staff, and the continuation of regular records and reports—enough to keep a skeleton crew at work.





Image 126: For almost thirty years, the facility remained sealed and constantly monitored to ensure that no contamination escaped. However, aesthetic maintenance was not as important, as shown by the peeling paint on the once shiny reactor dome. (1981) (NASA C-1981-4957)

In 1976, a new proposal to NASA headquarters suggested four options for the future of Plum Brook Station. The main recommendation was for an estimated three-year, \$1,200,000 reactor-decommissioning project. Decommissioning was considered so costly NASA decided to maintain the reactor in standby mode. The problem was that the costs to keep the facility mothballed rose dramatically every year. In 1979, it was estimated that retaining the reactor in standby condition cost \$230,000 annually. Meanwhile, a new 1979 analysis estimated that decommissioning the reactor

facility would require six years and \$14,744,000. Again, NASA declined to decommission it. Eventually, however, the agency could not ignore the rising costs. NASA knew that it would have to perform this task, and with each year the decommissioning growing more expensive, it finally decided to allocate the funds for the project in 1998.

Returning the Land

Visiting the Plum Brook reactor today is like exploring a modern day archeological preserve. It is an eerie Pompeii-like place where the physical remains of the reactor's final hours have been left untouched. Papers remain on desks, paint peels from the walls, calendars stand frozen in time in June 1973, dusty equations linger on blackboards, and tools are still scattered on workbenches. Numerous ashtrays, some built into the testing machines themselves, bear the scars of thousands of cigarettes ground into them over the years. Posters from J. Edgar Hoover and the FBI continue to admonish, "A theft from your government is a theft from YOU!" In contrast to the artifacts that were left haphazardly forgotten, meticulous attention was given to maintaining the reactor core and ensuring its environmental safety. It is a testament to the scientists and engineers who were responsible for closing down the reactor that none of its structures began to physically deteriorate and endanger the surrounding community.

The reactor remained in this mothball state for a quarter century until it opened once again, but this time not for research. In 1998, NASA requested annual renewal of its "possess but do not operate" license from the NRC. The NRC responded by asking NASA to consider decommissioning the entire reactor because it was becoming increasingly expensive to maintain the facility and the half-life of many of the isotopes had lapsed, making it safer to tear down. NASA agreed and approved the funds to dismantle the facility with a projected completion date in 2007. In December 1999, NASA submitted a decommissioning plan to the NRC.⁶⁴

The plan described an extensive decommissioning process through which, piece by piece, the entire building would be dismantled. Engineers planned to transform the 117-acre site into an empty field, with an assurance to environmentalists that the ground would be safe enough for a family to actually live on the land, grow crops on



Image 127: Despite the fact that decommissioning work had been on-going since 2001, the felling of the 193-foot-tall double water tower was one of the first external signs that the Plum Brook reactor was being dismantled. The tower stood adjacent to the Reactor Facility from 1959 until its demolition in October 15, 2003. Workers placed explosive charges on the legs of the tower to collapse it in a controlled manner. The felled tower was then cut into pieces and shipped offsite for disposal. (NASA C-2004-742), (NASA C-2004-743), (NASA C-2004-744), (NASA C-2004-745)





Image 128: Above, Dean Sheibley and Barbara Johnson perform studies in the Plum Brook chemistry lab in 1961 before the reactor was shut down. (NASA C-1961-55639)



Image 129: The chemistry lab forty years later, in 2001. The Plum Brook reactor, once a lively research center, had become a ghost town. (NASA C-2001-1173)



Image 130: Bill Fecych (seated) and Don Johnson work in the reactor control room during its operating days in 1959. After an ad hoc committee study in 1977, NASA Headquarters decided that the reactor would never be put back into operation. Reactor equipment was then “cannibalized” for other programs. (NASA C-1959-51506)



Image 131: The Plum Brook reactor control room in 2001, stripped of a significant amount of its instrumentation. (NASA C-2001-01221)





Image 132: Above, after serving as the site for the Ordnance Works pentolite production facility and the NASA reactor for over sixty years, this land will be restored by the decommissioning process to a condition safe enough to allow crops to be grown upon it again. (NASA C-2001-01214)



Image 133: An existing natural field at Plum Brook Station. (NASA Glenn Environmental Management Office)



Image 134: Decommissioning manager Tim Polich (second from left) and Keith Peecook (right) consult with former reactor employees Jim Martz (left), Len Homyak (third from left), and Jack Crooks (second from right). Retired Plum Brook employees have assisted the decommissioning team throughout the decommissioning process. (2002) (NASA C-2002-1023)

it, drink water, and raise livestock.⁶⁵ Great care would be taken to decontaminate everything that came into contact with radiation before being transported to landfills in Utah and South Carolina. Keith Peecook, senior project engineer, observed, “It’s not just going in with a wrecking ball, it’s a little more surgical in nature.”⁶⁶

The cornerstone of the plan was a federal partnership between NASA, the U.S. Army Corps of Engineers (USACE), and Argonne National Laboratories (a section of the U.S. Department of Energy). USACE was an important partner because it had extensive experience managing large cleanup and construction projects. It also served as an important link to expertise in the private sector.

USACE hired Montgomery Watson Harza from Pasadena, California, as prime contractor for the project. Duke Engineering Services from Charlotte, North Carolina, and MOTA Corporation from Columbia, South Carolina, were also chosen as subcontractors to assist with the engineering challenges.⁶⁷

Despite the importance of the team, NASA was the organization that was ultimately responsible for the decommissioning process. Tim Polich left the NRC to become NASA’s decommissioning manager in 1999. He and his team became responsible for overseeing the entire process, which is sometimes conceptualized as construction in reverse. Unlike conventional building from the





Image 135: In September 2002, Plum Brook Station held its third reunion for former employees. About 250 people attended. While the reactor itself was closed because of the decommissioning process, most of the retirees did not even visit the site's exterior because they wanted to remember the way it was, and not in its current state of disrepair. (NASA C-2002-01879)

ground up, Polich and his team are literally proceeding from the roof to the ground. This includes removing and safely disposing all radioactive materials, decontaminating and demolishing all of the buildings at the site, and finally backfilling the entire area with clean fill dirt. On 21 March 2002 the NRC officially approved the decommissioning plan. NASA Glenn Research Center director Donald J. Campbell said that the NRC approval of NASA's approach "reflects confidence in the capabilities and experience of our project team... The pre-decommissioning activities to date were just the beginning; now the real work begins."⁶⁸

Throughout the decommissioning process, safety issues continue to be a primary focus to protect the workers, the surrounding community, and the environment. Tim Polich affirmed that

"NASA is committed to the safest method of decommissioning these reactors."⁶⁹ Every worker and visitor to the reactor is given extensive training and must pass a test to prove awareness of radiation safety issues. Everyone who goes inside the reactor carries a personal dosimeter, which indicates an unplanned exposure to radiation. Also, upon leaving the reactor, everyone must pass through full-body radiation monitors to detect any trace amounts of contamination.

The nearby community is kept informed through the Multifaceted Community Relations Plan, which was established to educate the public about decommissioning activities. It also conducts extensive research with people from the surrounding area to ensure that they understand what is happening behind the secured Plum Brook fences.



Image 136: In April 2002, Keith Peecook led the Decommissioning Community Workgroup on a tour through the reactor facility. The tour was designed to demonstrate the safety measures in force during the decommissioning process. (NASA C-2003-852)

NASA assures the community that any family living in the area will receive no more than a dose of twenty-five millirems of radiation per year because of their proximity to the reactor. Ohio residents on average receive about 360 millirems per year from the sun, and the government has limited the radiation dose that a worker may receive on the job during any year to no more than 5,000 millirems. Those who work at the site every day during a year will likely receive only about one-fifth that amount.

Environmental precautions are also rigorously followed. Every week air samples are taken, and water samples from the area are collected every month for analysis at an offsite laboratory. The Plum Brook decommissioning is considered

NASA's largest environmental project, not only because of the importance of safely disposing of radioactive remains, but also because the surrounding area is a unique natural preserve.

Despite being home to the production of nearly one billion pounds of gunpowder during World War II and two nuclear reactors since 1961, much of the protected area inside the Plum Brook fences remains remarkably unspoiled. Today Plum Brook's 6,400 acres of land demonstrate an incredible ecological variety and vitality, including 521 plant, 125 breeding bird, 21 amphibian/reptile, 16 fish, 53 butterfly, 450 moth, and 8 bat species. Several of these are protected by the Endangered Species Act, which maintains that federal agencies cannot jeopardize the existence of any threatened spe-





Image 137: This swampy wetlands area is home to a Saturated Shrubland Alliance of dogwoods and willows. Plum Brook Station's approximately 5,400 acres contain a wide variety of wildlife and natural habitats, including fields, meadows, forests, and wetlands. (NASA Glenn Environmental Management Office)

cies. Plum Brook has 20 plant, 8 bird, 3 amphibian/reptile, and 1 moth protected species. Eleven populations of Least St. John's Wort grow at Plum Brook, which represents the largest concentrations of this plant in Ohio. The Sedge Wren uses the area as one of the most important breeding grounds for its species. In recent years a Bald Eagle pair built a nest at the facility and onlookers were treated to the rare sight of baby eagles.

The Plum Brook forests and plains are also unique. The central meadows area is significant because Ohio has no other native prairie locations like it. Though the presence of humans has restricted its natural growth, through proper cultivation it has great potential to be restored to its original condition. The west area native forests are also important. According to Mike Blotzer, chief of the Environmental Management Office at Glenn Research Center, "[The region] may be one of the

most significant remnant forest areas in the Ohio Lake Plain. It is unique as a remarkable representation of Ohio forest conditions at the time of the early settlement in the early 19th century."⁷⁰

Ironically, the land the government forcibly acquired through eminent domain in 1940 for use as an ordnance works—and later as the home of NASA's most powerful nuclear test reactor—will once again be restored to its natural condition. From the natural frontier, to the nuclear frontier, and back again, the Plum Brook land demonstrates the resiliency of nature and its adaptability to modern development. But what must not be forgotten is that without the emphasis on safety and environmental preservation by NASA's scientists and engineers, the dangers of nuclear research might have forever contaminated an important piece of our American heritage.



Image 138: Ashy sunflower plants are scattered around Ohio, but the Plum Brook Station probably has the state's largest natural population. A 1994 survey found the population near the intersection of Fox and Patrol Roads had been decimated by deer grazing. No flowers or fruits were observed that year, but the species had recovered dramatically by 2001, apparently due to the deer management that has been practiced within the facility. (NASA Glenn Environmental Management Office)



Image 139: Despite being cleared and drained for farming long before World War II, Plum Brook Station contains a wide variety of forest areas. This seasonally flooded Forest Alliance of pin oaks, and the many other wooded areas, are no more than sixty years old—and may be younger than that. (NASA Glenn Environmental Management Office)





Image 140: Plum Brook Station's protected fence line has created a sanctuary for a plethora of wildlife populations. The deer population inside the fence is often in excess of 2,000. Controlled hunts are occasionally scheduled to keep the number of deer in proportion with a sustainable habitat. (NASA C-2003-853)



Image 141: In recent years, Bald Eagles have been observed nesting at Plum Brook. (NASA C-2004-771)



Image 142: Artist's rendering of a nuclear rocket capable of reaching the Moon in 24 hours. This image was developed for NASA by Pat Rawlings and Bill Gleason (SAIC). (NASA S99-04186)

Though Kennedy's dream of a nuclear rocket went unrealized in the 1960s, it has now become one of NASA's most pressing goals for the future. NASA is revisiting the advantages of designing and constructing nuclear rockets for space exploration and an eventual human voyage to Mars. NASA Administrator Sean O'Keefe outlined NASA's new nuclear vision for the future in April 2002, which includes the launch of space probes to the outer solar system.

After Plum Brook's shutdown, few other reactors continued to study the effects of radiation on

materials in space. In the end, Plum Brook's basic research into the effects of radiation on materials may serve as an important starting point for the rejuvenated nuclear program. Many of the materials that might be used for the new nuclear initiative were originally tested in the Plum Brook reactor decades ago. Though the reactor is now quiet, its archived data can be resurrected and put to use as America begins a renewed quest to explore the frontiers of outer space with nuclear rockets.



Primary Document #7

NASA Administrator Sean O’Keefe delivered his vision for the future of NASA on 12 April 2002 at the Maxwell School of Citizenship and Public Affairs, University of Syracuse. He recommitted NASA to pursuing a nuclear rocket as the best hope for exploring the solar system. The following is an excerpt of that speech, focusing on his plans to develop nuclear rockets.

“PIONEERING THE FUTURE”

Sean O’Keefe

NASA Administrator

April 12, 2002

...In broad terms, our mandate is to pioneer the future, to push the envelop, to do what has never been done before. An amazing charter indeed. NASA is what Americans, and the people of the world, think of when the conversation turns to the future.

...What NASA needs now is a roadmap to continue our work in a more efficient, collaborative manner. Our imperative is not only for the sake of knowledge—it is for our future and our security. Today I am introducing a new strategic framework and vision for NASA. It is a blueprint for the future of exploration.

...NASA has to do things differently in the future. One fundamental difference is a need to find new ways to explore the galaxy. Conventional rockets and fuel simply aren’t practical as we reach further out into the cosmos. That’s why we are launching an initiative to explore the use of nuclear propulsion.

One of the major obstacles of deep space travel is finding fast and efficient ways to get around, to get to anywhere. Today’s spacecraft travel at speeds slightly faster than John Glenn’s Friendship 7 did 40 years ago. NASA has explored the use of solar sails and ion engines as alternatives to conventional fuels, but their uses are limited and restricts us to very close-in objectives, or if used for deep space exploration, require us to wait a long time before we see results—a minimum of 10 years for example, to get to the edge of our own solar system, and a lot longer if we miss the “sling shot” effect of optimum planet alignment. So the nuclear propulsion initiative is the next logical step to overcome this technology limitation. It’s a mature technology and its application to space travel has great potential. The U.S. Navy has been operating nuclear powered vessels since 1955. In that time, the Navy has sailed more than 120 million miles without incident, and has safely operated these efficient power generators for more than 5000 reactor-years. And throughout that time, the Navy has designed more compact, safer, and more efficient reactors, which last the 40-year life of the vessels without refueling.

The technology is there. We just need to take it to the next step to increase speed and on-orbit time, thereby beginning to overcome this persistent technical limitation. If we’re going to pioneer the future as only NASA can, we’re going to need new ways to get us there.

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Appendices



Image 143: Gazing into the abyss, employees soak up the quiet calm of the Plum Brook reactor at night. Many times on the overnight shift, the operators would turn off the overhead lights in the control room and work by the glow of the indicator lights. In addition to having a soothing effect, this also brought out the indicator colors, so if there was any abnormality it jumped right out at the operator. Music was also piped into the control room. (1959) (NASA C-2003-852)

Timeline

- 1941** In January, U.S. Army announces Plum Brook site selection for an Ordnance Works (9,000 acres). It begins buying options on properties and town meetings are held. In March, the remainder of deeds are purchased. Residents are given until April to vacate. In April, E.B. Badger & Sons begin construction. In September, a dedication ceremony is held. In November, Plum Brook's first trinitrotoluene (TNT) production line begins operation, twenty-two days before Pearl Harbor is attacked by Japan.
- 1942** In August, Abbott & Costello visit Plum Brook Ordnance Works as part of war bond campaign.
- 1943** In April, the B-17 bomber bought with Plum Brook bonds is christened the Plum Brook Trojanair. The first research reactor is built at the University of Chicago.
- 1945** In May, Germany surrenders; in August, Japan surrenders. Plum Brook ceases producing munitions. In December, Plum Brook land is transferred from Trojan to the Army.
- 1946** War Assets Administration accepts custody of Plum Brook. The Atomic Energy Commission (AEC) is founded.
- 1947** Magazine area is renamed the Plum Brook Depot Activity.
- 1949** In May, NACA Lewis Laboratory acquires cyclotron for basic materials research. The Plum Brook land is transferred to the General Services Administration.
- 1951** NACA begins examining requirements to build research facilities and test nuclear engines for airplanes.
- 1952** In March, the Materials Test Reactor at Idaho Falls sustains its first nuclear reaction. It will serve as a model for the Plum Brook Reactor Facility.
- 1953** President Eisenhower delivers "Atoms for Peace" speech to the United Nations General Assembly.
- 1954** In January, the USS Nautilus, the world's first nuclear submarine, is christened. Nuclear school begins at Lewis. Army reacquires Plum Brook from General Services Administration; it becomes a satellite of the Ravenna Arsenal for the Korean War.
- 1955** Nuclear space initiative begins with two primary programs: Nuclear Engine for Rocket Vehicle Application (NERVA) and Space Nuclear Auxiliary Program (SNAP). NACA proposes concept of nuclear reactor facility to AEC. Site Survey for NACA Research Reactor published (September 13), and Plum Brook site is chosen. Congress approves construction of sixty-megawatt reactor. A B-36 bomber begins forty-seven flights over Texas with a nonpropulsive test reactor aboard.



- 1956** AEC announces testing in Idaho on stationary forerunner of the atomic aircraft engine. The NACA is given permission to use 500 acres for Plum Brook reactor. In September, ground is broken for the Plum Brook Reactor Facility. In October, NACA Reactor Facility Hazards Summary is submitted to AEC.
- 1957** In October, the Soviet Union launches Sputnik.
- 1958** In January, the Army transfers 3,180 acres to NACA for a five-year period. In March, the Plum Brook area is released from the jurisdiction of the Ravenna Arsenal. In June, 65 percent of the construction is complete. In October, the NACA transforms into NASA.
- 1959** In December, an updated Final Hazards Summary is submitted to the AEC.
- 1960** Provisional operating license is issued by the AEC. The joint AEC-NASA Space Nuclear Propulsion Office (SNPO) is formed. SNPO is given the responsibility to build the NERVA, the first nuclear rocket engine.
- 1961** In March, President Kennedy terminates the nuclear airplane program. In May, Kennedy lends support to the nuclear rocket program in his “Urgent National Needs” speech. Low-power testing is performed at Plum Brook in June. On 14 June 1961, the Plum Brook test reactor goes critical for the first time.
- 1962** In May, the United States Congress approves \$40 million expansion program for Plum Brook in the next fiscal year.
- 1963** In April, the reactor reaches full sixty-megawatt power for the first time. In July, it reaches criticality for its first experimental cycle, which is completed on August 15. Also in July, the Mock-Up Reactor (MUR) receives its license from the AEC. The MUR begins operation on September 5 and goes critical for the first time on September 10. In October, over 1,600 people visit the Plum Brook reactor during a public relations event. In December, the hot laboratory becomes operational.
- 1964** Plum Brook reactor completes its first year of operation at full power. The first fueled experiment is run in the reactor in August.
- 1966** The Plum Brook reactor completes its 50th cycle.
- 1969** The Plum Brook reactor completes its 100th cycle.
- 1970** The reactor begins investigations for the Environmental Protection Agency.
- 1972** In December, the last astronauts walk on the Moon with Apollo 17.
- 1973** In January, NASA Lewis director Bruce Lundin announces immediate shutdown of reactor. All experimental programs end that day. By June, “mothballing” of the reactor is complete.
- 1974** Bob Didelot begins work as standby manager; he maintains this job until 1980. The AEC is suspended and becomes the Nuclear Regulatory Commission (NRC).



- 1976** Four future uses for the Plum Brook reactor are suggested to NASA headquarters.
- 1977** The decision is made to not restart the reactor. Reactor equipment begins to be cannibalized by other programs.
- 1978** Teledyne performs a decommissioning options study.
- 1980** In January, a decommissioning project office is established at Lewis Research Center. In March, NASA submits a five-year dismantling plan to the NRC. In September, Earl Boitel becomes new Plum Brook reactor standby manager.
- 1981** In May, the order to dismantle is not carried out for budget reasons.
- 1983** In April, the Plum Brook Procedures Manual is completely rewritten to reflect pre-dismantling work. Radiological surveys are performed on the cooling tower and disposal basins. In July, the reactor cooling tower is razed and burned.
- 1984** The Plum Brook reactor is granted a “possess but do not operate” license.
- 1985** In January, cracks in pipes allow liquid to leak into basement of the hot lab. In July, NASA requests a return to “possess but do not operate” license and rescinds dismantling order. In October, Hank Pfanner becomes new standby manager.
- 1987** In January, a “possess but do not operate” license is reinstated for a ten-year period.
- 1989** In March, Sverdrup Technology, Inc., assumes control of maintaining the reactor and operating test sites.
- 1996** A \$900,000 maintenance project performed.
- 1999** In December, NASA submits its decommissioning plan to NRC. Tim Polich becomes NASA’s decommissioning manager.
- 2002** In March, NRC approves the Plum Brook plan and decommissioning starts. In April, NASA administrator Sean O’Keefe outlines a new vision for a nuclear rocket.
- 2007** Projected completion date for Plum Brook reactor decommissioning.



Reactor Experiments

Note: Data from this table was compiled from the 152 reactor-cycle reports located in the NASA Plum Brook Station Library. The cycle column refers not only to when the experiments were in the reactor, but also indicates when preparatory work began in setting up the equipment.

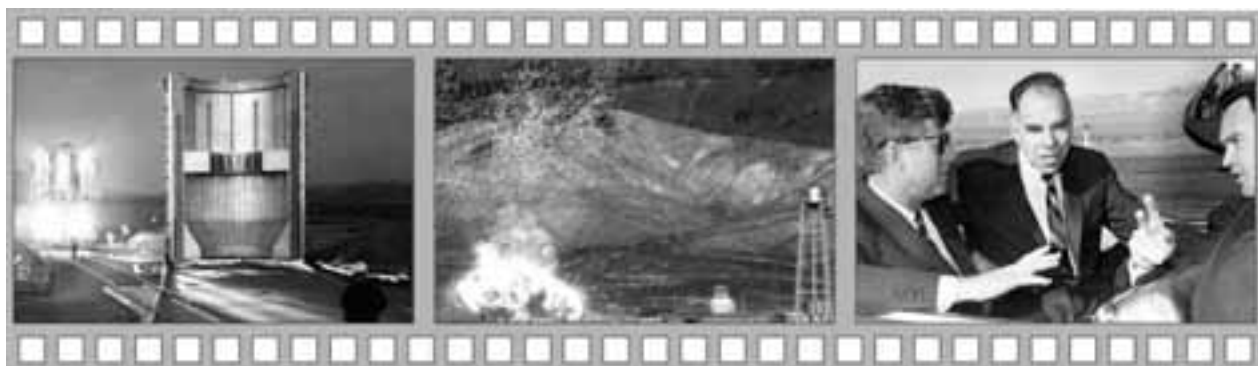
Exp. Number	Cycles	Name	Description
62-01	3,5–84	Lockheed Cryogenic Experiment	Determined the effects of radiation on materials at cryogenic temperatures.
62-02	36–52 54–63, 75	In-Pile Helium Cooled Loop	Aided in evaluating loop performance under gamma heating on the in-pile experiments. A great deal of effort went into preparing equipment for this type of experimentation.
62-03	3–11 30, 31, 33–45 58–61, 64, 75–79, 83–88, 92–94, 96–100 102–103	Neutron Scattering and Diffraction Experiment	Provided a collimated beam of gamma and neutron radiation for use by experimenters.
62-04	76, 78–152	Irradiation of Solid Film Lubricants	The experimental data for this test was programmed on the EDLAS computer. Utilized a collimated beam of thermal neutrons emerging from HB-4 to conduct experiments in basic physics, and more specifically in neutron diffraction studies. For example, during one cycle fifty-two data point runs were made with a barium chlorate monohydrate crystal. During another, ninety-three data points were made with a calcium bromate monohydrate crystal.
62-05	19, 21–31, 33–91 93–111	Neutron Diffraction	



Exp. Number	Cycles	Name	Description
62-05R1		Interim NERVA Irradiation	Modifications to the previous experiment were made to improve the reliability of the system.
62-06	30, 45–49 55–75	General Electric NERVA Actuator	After a great deal of setup time, in November 1967 drum actuator type AG20 was irradiated for sixty-five minutes at sixty megawatts of power.
62-07	3, 5–8, 12–15, 19–24, 30	Mallory and Tungsten Irradiation	Determined the radiation effects on material properties and corrosion resistance of Mallory 1000 and pure tungsten.
62-07R1	76–78	Radiation Effects on Material Properties of Tungsten	A capsule that contained thirty tungsten tensile test specimens was irradiated.
62-09	3	PB Space Propulsion Facility Activation Measurement	Determined the optimum material composition for walls at Plum Brook's Space Propulsion Facility. Rabbits were irradiated with samples of unclad and cadmium-clad 304 stainless steel, and unclad and cadmium-clad 5083 aluminum.
62-12	19, 21, 23–45 49, 51–53, 55, 62, 63, 65, 70–72 76, 79, 91 96–100, 102–104, 108, 109, 111, 118, 146	Fueled Material Specimens Irradiation	Evaluated the fuel and fission product retention qualities of tungsten-uranium dioxide dispersions, which are fission heated to anticipate rocket fuel element operating temperatures. Capsules from this experiment were sent to the Battelle Memorial Institute and the Westinghouse Electric Corporation for postirradiation examination.



Exp. Number	Cycles	Name	Description
62-12R1	73–75, 77, 78, 81, 82, 85–93, 95–152	Fueled Material Specimen	A series of tests determined the extent of irradiation uranium dioxide relocation and densification in small fuel pins operating at high-clad surface temperatures. During Cycle 88, engineers irradiated a stainless steel shell-type capsule containing a sealed fuel pin. The purpose of this experiment was to provide the capsule that was required for checkout of the Plum Brook hot cell fracturing device and to determine the extent of pressure buildup in the sealed fuel pin.
62-13	102–103, 105		
62-13R1	42–45	Thermionic Materials Irradiation	
62-13R2	80–116, 118, 119, 124–126	Thermionic Materials Irradiation	
62-14	3–105, 107–152	Irradiation of PBRF Materials	Investigated the long-term effects of critical materials used in the construction of the reactor. For example, in Cycle 4, sixty carbon steel specimens were irradiated that were identical to the material that was used in construction of the reactor pressure tank.
62-15	20–73, 97	Fueled Refractory Compounds Irradiation	Studied the effects of irradiation of refractory fuel components at high specific power to high burnups. This was the first fueled experiment. It was sponsored by Westinghouse.
62-16	64, 65, 76	NERVA Components Irradiation	Included shielding materials tests.



Exp. Number	Cycles	Name	Description
63-01	11–28	Measurements of Materials for SPF Walls	Tested the radiation effects on the full-scale thickness of the Space Propulsion Facility chamber walls. This included aluminum plate and foils and nonborated concrete block.
63-02	25–27, 30	Thermal Conductivity of Refractory Fuel Compounds	Continuously measured the in-pile thermal conductivity of high-density UO ₂ fuel at temperatures up to 2,200 degrees Celsius.
63-03R2	82–87, 95–98, 100–112, 119–122, 126–128, 130–134, 137–139	Thermionic Diode Irradiation	The diode was irradiated at defined temperatures to see how it would react. During Cycle 83 the diode would not generate current.
63-03	28–38, 58 60, 76, 93, 94, 100, 115 116, 122	Martin Thermionic Diode Irradiation	Demonstrated the reliable performance of a state-of-the-art thermionic diode in a nuclear reactor.
63-04	76, 78–84 88, 93, 95–98	Thermionic Reactor Fuel Form and Insulator Irradiation	Thermocouple readings were measured as the experiment capsules were subjected to helium and argon at various power levels in the reactor. Polaroid photos were then sometimes taken of the disassembled capsules.
63-05	48, 14, 16, 17, 20, 22, 28, 29, 55, 58, 60	Westinghouse Interim NERVA Experiment	Provided information on materials selection for components used for the NERVA reactor designed by the Westinghouse Astronuclear Laboratory.



Exp. Number	Cycles	Name	Description
63-05R1	30–48, 58	NERVA Transducer Irradiation Program	Sponsored by Westinghouse, this modified the previous 63-05 experiment through the addition of a Charging Table. Other modifications included an HT-1 isolation valve, a capsule seal assembly, a seal pump, controls for the table drive, a pump, a valve motor, and new piping.
63-07	36	Rabbit test of Mallory Material to establish source of tungsten in coolant	Investigated the tungsten 187 buildup in the primary cooling water system during the reactors full-power reactor operation.
63-08	14, 15	Sperry Experiment: Irradiation of Digital Computer Components	Evaluated the radiation temperature resistance of materials used in digital computer switching circuits.
63-09	8, 24–75 122	Nuclear Electric Sub-Systems and Component Irradiation	Investigated the effects of neutron and gamma radiation on the input and output parameters of nuclear-electric components and subsystems. The experiment was for the SNAP-8 program. In Cycle 32 a sheet metal “roof” was constructed over the instrumentation rack to prevent damage from water drippage.
63-09R1	76–79 81–88, 92–96, 99–105, 107–129	Nuclear Electric Subsystems and Components	Testing included a foil plate and holder with thermocouples attached. Argon-41 buildup and biological shielding effectiveness were tested.
63-10	23–30	Alumina Insulators Irradiation	Examined the effects of radiation on the electrical resistivity of high-purity alumina insulators.
63-11	10, 11		Investigated radiation effects on tungsten metal. Most important, it examined the elastic recoil mechanism of tungsten and also tungsten effective resonance integral measurements.



Exp. Number	Cycles	Name	Description
63-11R1	31		Two rabbits with tungsten specimens and flux measuring foils were irradiated for sixty seconds. They were then packaged in the hot lab and sent to the experiment sponsor.
63-12	46–56, 58	Radioscope Electrical Generator	
63-12HL	45, 57–61, 88, 93–96, 98–103, 105	Radioscope Electrical Generator	Tested and evaluated the concept of direct conversion of the kinetic energy of radioscope decay into electrical power.
64-01	58	Irradiation of Fuel/Clad Emitters	Performed for General Electric sponsor in California.
64-01R1	38–58	Fuel/Clad Emitter Irradiation	Modifications were made to improve previous experiments.
64-02	12–14, 30–34, 36	Copper Irradiation	Produced the Cu-64 isotope by exposing a high-purity copper foil to a thermal neutron flux. The Cu-64 could be used as a positron source to investigate the behavior of positronium in liquid gases.
64-03	12, 20		Produced a radioactive source (sodium-24) of such magnitude that it can be used to evaluate the decontamination efficiency of the newly built evaporator located at the PBRF waste handling building.
64-04	22, 24–26, 28–43, 50, 51, 65	Concrete Materials Trace Element Control	Determined by neutron activation of concrete samples whether or not the sample batch is satisfactory for the construction of the Space Propulsion Facility biological shield.
64-06	89–92, 95, 97, 98, 100–105, 107–112, 117–119	Radiation Damage Experiments in Ion Complexer and Exchanger Systems	The purpose of this experiment was to procure basic data necessary to determine the feasibility of a concept for control of a water-moderated nuclear reactor.



Exp. Number	Cycles	Name	Description
65-01	40	Production of Uniform Line Source	Thirty-eight target specimens were loaded into two rabbits. Deionized water was added to each of the rabbits, which were then welded shut. One rabbit was then irradiated for just over sixty-one hours and inspected. The rabbit ruptured. A modified vent was designed to enable the rabbits to remain sealed and the experiment continued for a full eighty-hour irradiation.
65-02	41, 42, 44	NaCL Crystals	Three NaCL crystals were placed in polyethylene containers and loaded into three rabbits and irradiated.
66-01	44, 54, 59–62	Irradiation of Various Insulating Materials	Two Al_2O_3 crystals were irradiated for Materials 574.4 MWD in a rabbit. A silicon carbide crystal was also irradiated at sixty megawatts for twenty-four hours and then sent to Lewis Research Center for analysis.
66-03	76, 77, 80–82, 84, 85	Irradiation of Bulk UO_2 Fuel/Clad Bodies	These experiments included lengthy irradiations. For example, during Cycle 80 a capsule was operated at the desired temperature for 241 hours.
66-03-01	78, 79, 83 86–94	Irradiation of Bulk UO_2 Fuel/Clad Bodies	
66-03-2	95–98, 100–119, 121, 123	Irradiation of Bulk UO_2 Fuel/Clad Bodies	In Cycle 105 the capsule was inserted into the reactor tank in one-inch increments to obtain the designed operating temperature. The capsule was then withdrawn completely in one motion, letting the temperature stabilize. This was done fifty times as quickly as possible to study the effects of thermal cycling on the fuel and thermocouples.



Exp. Number	Cycles	Name	Description
66-05	47, 76	Neutron Irradiation of Ammonium Bromide	A five-milligram sample of ammonium bromide (NH ₄ Br) was irradiated for thirty minutes at sixty megawatts and sent to Lewis Research Center for analysis.
66-06	92-105, 107-152	Fission Gas Retention Studies	In Cycle 106 the irradiation lasted 330 hours, or 93 percent of the total time available for that cycle. The fuel pin was operated at three temperature levels. Fission gas release data was also collected with the online detection instrumentation. The capsule contents were UO ₂ .
66-07	59-66	Charpy Impact Specimen Irradiation	Two capsules with weld specimens in aluminum alloy and alloy were initially irradiated for an entire cycle in the reactor.
66-08	73-75, 80, 81, 84, 86-88	Irradiation of a Rare Gas Filled Thermionic Diode	This experiment was installed into the experiment 62-16 (NERVA irradiation) water-cooled capsule.
67-01	58-61, 63-65, 81	Irradiation of Glassy Silicates	Six irradiations were initially performed in the rabbit facility and the specimens were sent to the Case Western Reserve University for analysis.
67-04	87-105, 107-123	Radiolysis of Water	The objective of this experiment was to investigate the pressure buildup and composition of gases resulting from the radiolysis of water in sealed aluminum containers.
67-05	71-82	Micrometeorite Irradiation	Consisted of three powder containers that held two major crystalline silicates of meteorites (Olivine and Enstatite) and six flux monitors.



Exp. Number	Cycles	Name	Description
67-06	76–78, 80–88, 92	Nuclear Reactor Materials Evaluation	Included testing like an experiment in Cycle 93. This included seven wear test specimens for metallurgical examination. Also, eighteen fatigue and six tensile specimens were placed in Hot Cell 1 to await reloading into future capsules for irradiation. Corrosion tests were also started on twenty-one specimens in 200 degrees Fahrenheit deionized water. The fatigue testing equipment was built by the Material Testing Systems (MTS).
67-06-71	94	Nuclear Materials Evaluation Program	
67-06-81	94–96, 98, 103, 105, 115–140	Fatigue and Tensile Properties of Irradiated Materials	
67-06-91	99–105, 107–112, 120–127, 129–142	Irradiation of NERVA Materials	Materials included Waspaloy, Inconel, and General Dynamics test specimens.
67-07	76, 77, 79, 81, 82, 91, 94–112, 114–139, 142–150	Irradiation of Gas-Cooled Fuel Pins for Compact Reactors	This experiment arrived at the reactor from Oak Ridge on 21 May 1968. One test (Cycle 103) attempted to measure the diffusion rate of gaseous fission products in a static system.
68-01	76–79–82, 84, 86, 87, 89, 104, 107–109	Irradiation of Plastic Containers	Over twenty-five samples of plastic were irradiated for various lengths of time and analyzed in the hot lab. This increased to fifty samples in Cycle 81. In Cycle 104, fifteen plastic vials that contained lead, aluminum, or air samples were irradiated and analyzed at the radiochemistry laboratory.



Exp. Number	Cycles	Name	Description
68-03	105, 128–139	Nuclear Thermionic Ceramic Insulators	
68-04	89–91, 94, 95	Radioactive Tracer Production for Tektite Research	
68-05	92, 94, 100–102, 105–142	Irradiation of High-Temperature Thermocouples	The temperature of the irradiations was 1,600 degrees Celsius.
68-06	93–101, 103–105	Hot Laboratory Examination of Irradiated Tri-Layer Specimens	Sponsored by Oak Ridge. The high-temperature vacuum furnace was placed in Hot Cell 1. It raised the temperature of the experiment to 2,200 degrees Celsius with a vacuum. In Cycle 105, metallographic specimens were photographed at 250× and 500× magnification.
69-01-1	107–152, 93, 113	Nuclear Experiment Power Reactor Technology Fuel Capsule Irradiations I	Fuel pins received from the experiment sponsor were irradiated. In Cycle 107, samples of stainless steel were irradiated to determine the variation of cobalt content.
69-01-2	111–113, 115–152	Nuclear Experiment Power Reactor Technology Fuel Capsule Irradiations II	
69-01-03	139–152	Space Power Reactor Technology	
69-02	108, 109, 111, 128, 133, 144		
69-03	98–100	Irradiation of Apollo Glycol-Water Solutions	Vials containing glycol-water were irradiated for four hours (Cycle 98) and then analyzed in the radiochemistry laboratory.



Exp. Number	Cycles	Name	Description
70-01	106–107, 109, 112, 115, 116, 118, 123, 126, 128–131, 133, 135, 136, 139, 140, 143–145, 147–152	Irradiation of Lunar Soil	Several vials that contained 1.2 grams of lunar soil (Cycle 106) were irradiated in the rabbit facility for six days. The rabbit was then sent to the hot laboratory where the vials were removed, packaged, and shipped to the experiment sponsor. In Cycle 107, 0.6 grams of lunar soil, one gram of Columbia River basalt, and one gram of ordinary chondrites were irradiated for six days and the samples were sent back to the sponsor.
70-02	118–122, 124–137, 142, 143	Vapor Transport Fuel Pin Experiment	
70-03	111, 112	Irradiation of Pyrolytic Graphite	
70-04	112, 113, 115–119	Irradiation of Grain Boundary Impurities	In Cycle 115, five pairs of grain specimens were irradiated in the rabbit facility for ninety-four hours and then unloaded in the hot laboratory and sent back to the experiment sponsor.
70-05	111, 118, 120, 126, 130–134, 137	Irradiation of Lunar Soil, Meteorites, Terrestrial Rocks, and Standards	
70-06	127, 132–152	Thermionic Reactor Fuel Form Irradiation	
70-07	117, 118	Irradiation of Meteorite Crystals	
70-08	117, 119, 120, 122, 123, 125, 126, 128–152	Irradiation of Particulate Materials from Cuyahoga County Air Samples	



Exp. Number	Cycles	Name	Description
70-09	117, 118, 120, 121, 123, 126, 129, 130, 133, 134, 136, 139–142, 147, 151	Irradiation of Extraterrestrial Material	During Cycle 119, 25 specimens of aluminum were loaded into the cryogenic capsule and irradiated at a temperature below seventy-seven degrees Kelvin.
70-11	125, 138–144, 146–151	Loss of Coolant Experiment	
70-12	118–146, 148	Irradiation of NERVA Materials at Cryogenic Temperatures	
71-02	142, 143, 145, 150–152		
71-03	124–129, 131, 133–138, 140, 151	Determination of Mercury and Selenium in Air Particulate	
71-03R1	139, 141–147, 149, 150, 152	Determination of Hazardous Trace Elements in Samples and Fuels	
71-05	128, 132, 133, 136, 139	Radioscope F-18 Production	
71-07	135, 136, 140–144	Radiation of Reentry Heat Shield Material	



Exp. Number	Cycles	Name	Description
71-08	133, 134	Irradiation of Pure Silicon	
71-09	137–139	Irradiation of Corn	
72-01	143, 150–152		
72-02	140	Irradiation of Thin Silver Films	
72-03	149–152	Nuclear Power Reactor Technology IV	
72-04			
IT-A-I		Neutron Radiographic Facility	This was located in quadrant A. It used a voided tube to direct a neutron beam through a specially designed fifteen-foot-long collimator. The collimated beam of thermal neutrons that emerged provided a three- by thirty-inch area suitable for radiography. For example, in Cycle 89, tests included evaluating different types of X-ray film provided by Eastman Kodak and Agfa-Gevaert. It was also used to irradiate fuel pins.

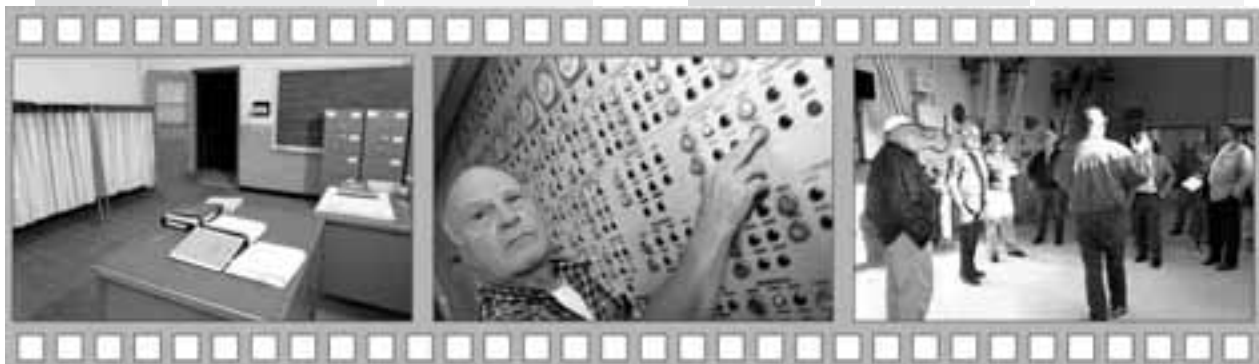


Reactor Cycle Dates

Cycle	Start Date	End Date	Cycle	Start Date	End Date
1	2/12/1963	3/13/1963	45	5/3/1966	5/20/1966
2	3/13/1963	4/29/1963	46	5/20/1966	6/6/1966
3	4/29/1963	8/15/1963	47	6/6/1966	7/18/1966
4	8/30/1963	9/8/1963	48	7/18/1966	7/26/1966
5	9/20/1963	9/26/1963	49	7/26/1966	8/8/1966
6	10/13/1963	10/19/1963	50	8/8/1966	8/24/1966
7	11/1/1963	11/9/1963	51	8/24/1966	9/11/1966
8	11/26/1963	12/6/1963	52	9/11/1966	9/19/1966
9	12/9/1963	12/20/1963	53	9/19/1966	10/26/1966
10	1/10/1964	1/21/1964	54	10/26/1966	11/13/1966
11	1/21/1964	2/5/1964	55	11/13/1966	11/22/1966
12	2/5/1964	2/28/1964	56	11/22/1966	12/14/1966
13	2/28/1964	3/10/1964	57	12/14/1966	2/23/1967
14	3/10/1964	3/25/1964	58	2/23/1967	3/28/1967
15	3/25/1964	4/5/1964	59	3/28/1967	4/15/1967
16	4/5/1964	4/22/1964	60	4/15/1967	5/28/1967
17	4/22/1964	4/29/1964	61	5/28/1967	6/20/1967
18	5/14/1964	6/27/1964	62	6/20/1967	7/8/1967
19	6/27/1964	7/12/1964	63	7/8/1967	8/26/1967
20	7/12/1964	7/25/1964	64	8/26/1967	9/13/1967
21	7/25/1964	8/6/1964	65	9/13/1967	10/15/1967
22	8/6/1964	8/24/1964	66	10/15/1967	10/25/1967
23	8/24/1964	9/30/1964	67	10/25/1967	11/5/1967
24	9/30/1964	10/3/1964	68	11/5/1967	11/19/1967
25	10/3/1964	10/27/1964	69	11/19/1967	12/1/1967
26	10/27/1964	11/15/1964	70	12/1/1967	12/13/1967
27	11/15/1964	12/4/1964	71	12/13/1967	12/29/1967
28	12/4/1964	12/19/1964	72	12/29/1967	1/22/1968
29	12/19/1964	3/7/1965	73	1/22/1968	2/4/1968
30	3/7/1965	3/27/1965	74	2/4/1968	2/17/1968
31	3/27/1965	4/8/1965	75	2/17/1968	6/22/1968
32	4/8/1965	5/6/1965	76	6/22/1968	7/15/1968
33	5/6/1965	5/25/1965	77	7/15/1968	7/31/1968
34	5/25/1965	6/30/1965	78	7/31/1968	8/9/1968
35	6/30/1965	7/24/1965	79	8/9/1968	9/25/1968
36	7/24/1965	8/9/1965	80	9/25/1968	10/27/1968
37	8/9/1965	9/2/1965	81	10/27/1968	11/18/1968
38	9/2/1965	11/7/1965	82	11/18/1968	12/3/1968
39	11/7/1965	11/23/1965	83	12/3/1968	12/24/1968
40	11/23/1965	12/14/1965	84	12/24/1968	1/15/1969
41	12/14/1965	1/14/1966	85	1/15/1969	2/5/1969
42	1/14/1966	1/28/1966	86	2/5/1969	2/20/1969
43	1/28/1966	2/19/1966	87	2/2/1969	3/8/1969
44	2/19/1966	5/3/1966	88	3/8/1969	3/28/1969

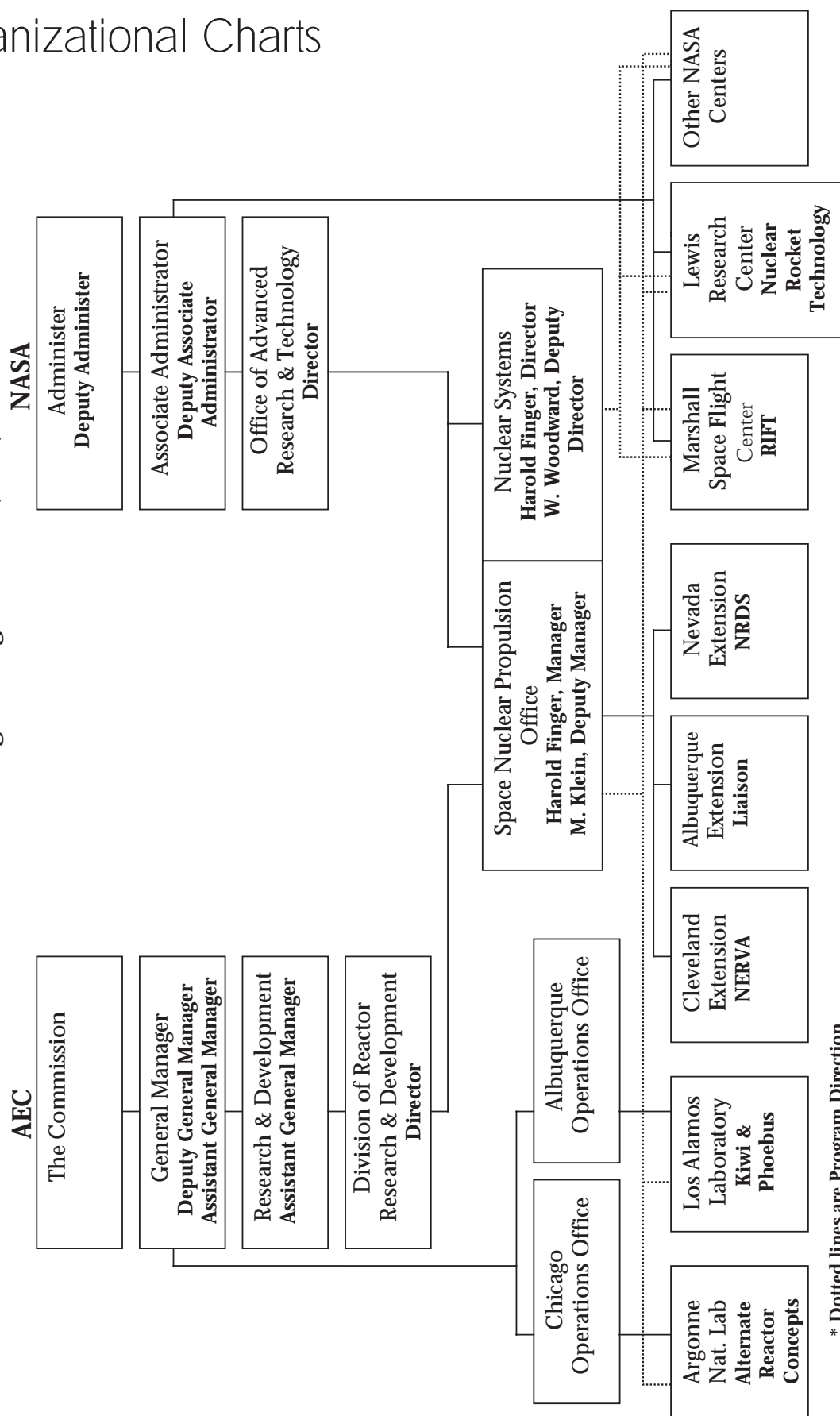


Cycle	Start Date	End Date	Cycle	Start Date	End Date
89	3/28/1969	4/14/1969	134	11/1/1971	11/23/1971
90	4/14/1969	5/14/1969	135	11/23/1971	12/20/1971
91	5/14/1969	6/11/1969	136	12/20/1971	1/14/1972
92	6/11/1969	6/30/1969	137	1/14/1972	2/1/1972
93	6/30/1969	7/25/1969	138	2/1/1972	2/26/1972
94	7/25/1969	8/22/1969	139	2/26/1972	5/19/1972
95	8/22/1969	9/14/1969	140	5/19/1972	6/3/1972
96	9/14/1969	10/13/1969	141	6/3/1972	6/23/1972
97	10/13/1969	11/3/1969	142	6/23/1972	7/11/1972
98	11/3/1969	11/19/1969	143	7/11/1972	7/27/1972
99	11/19/1969	12/9/1969	144	7/27/1972	8/14/1972
100	12/9/1969	12/24/1969	145	8/14/1972	8/29/1972
101	12/24/1969	1/15/1970	146	8/29/1972	9/17/1972
102	1/15/1970	2/8/1970	147	9/17/1972	10/6/1972
103	2/8/1970	3/1/1970	148	10/6/1972	10/29/1972
104	3/1/1970	3/23/1970	149	10/29/1972	11/24/1972
105	3/23/1970	4/10/1970	150		
106	4/10/1970	5/18/1970	151		
107	5/19/1970	6/5/1970	152		
108	6/5/1970	6/22/1970			
109	6/22/1970	7/9/1970			
110	7/9/1970	7/27/1970			
111	7/27/1970	8/17/1970			
112	8/17/1970	9/8/1970			
113	9/8/1970	9/28/1970			
114	9/28/1970	10/20/1970			
115	10/20/1970	11/8/1970			
116	11/8/1970	12/1/1970			
117	12/1/1970	12/18/1970			
118	12/18/1970	1/18/1971			
119	1/18/1971	1/30/1971			
120	1/30/1971	2/15/1971			
121	2/15/1971	3/7/1971			
122	3/7/1971	3/29/1971			
123	3/29/1971	4/9/1971			
124	4/9/1971	4/25/1971			
125	4/24/1971	5/17/1971			
126	5/17/1971	6/1/1971			
127	6/1/1971	6/26/1971			
128	6/26/1971	7/8/1971			
129	7/8/1971	8/5/1971			
130	8/5/1971	8/23/1971			
131	8/23/1971	9/11/1971			
132	9/11/1971	10/13/1971			
133	10/13/1971	11/1/1971			



Organizational Charts

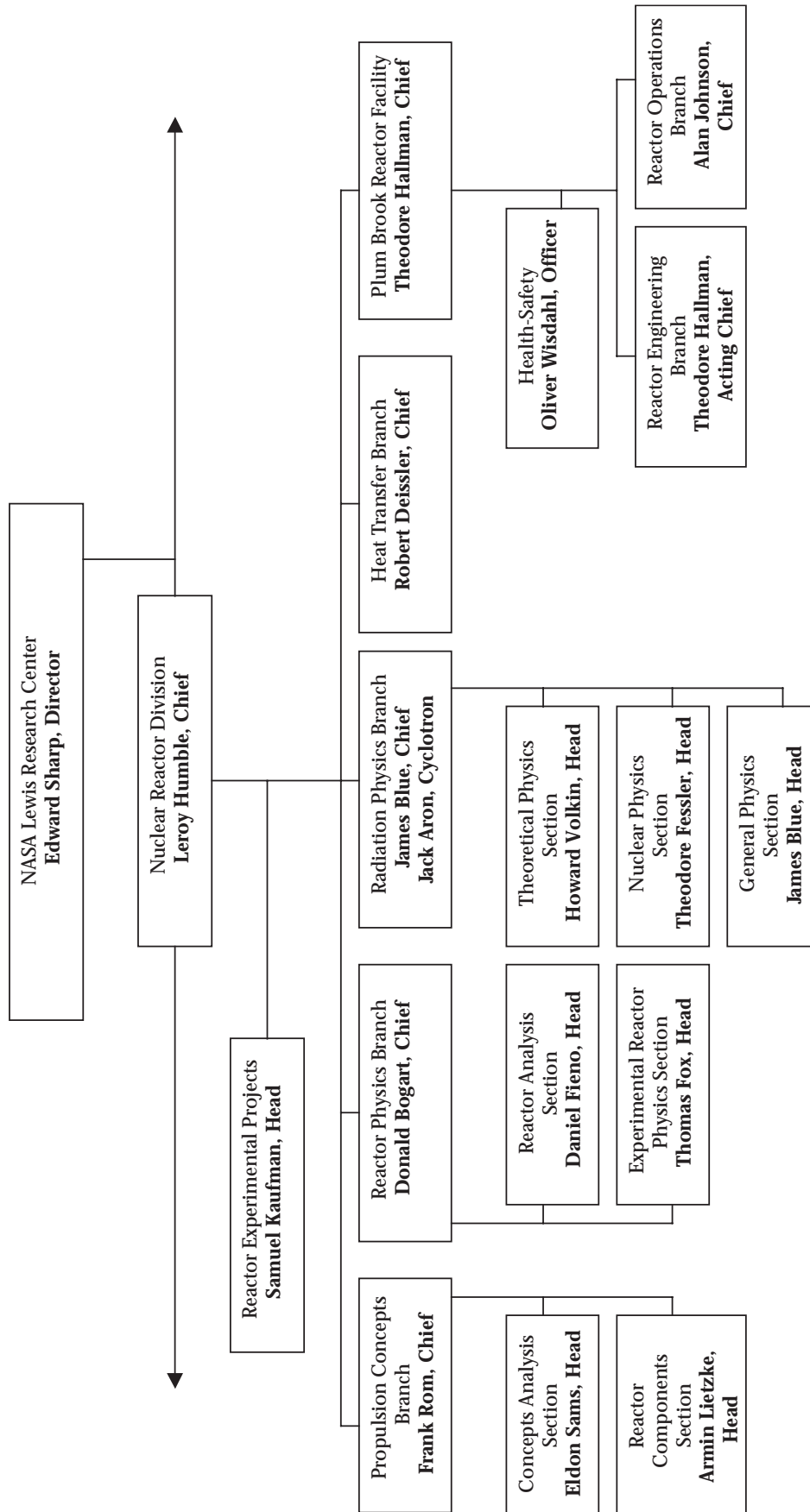
Nuclear Rocket Program Organization (1962)



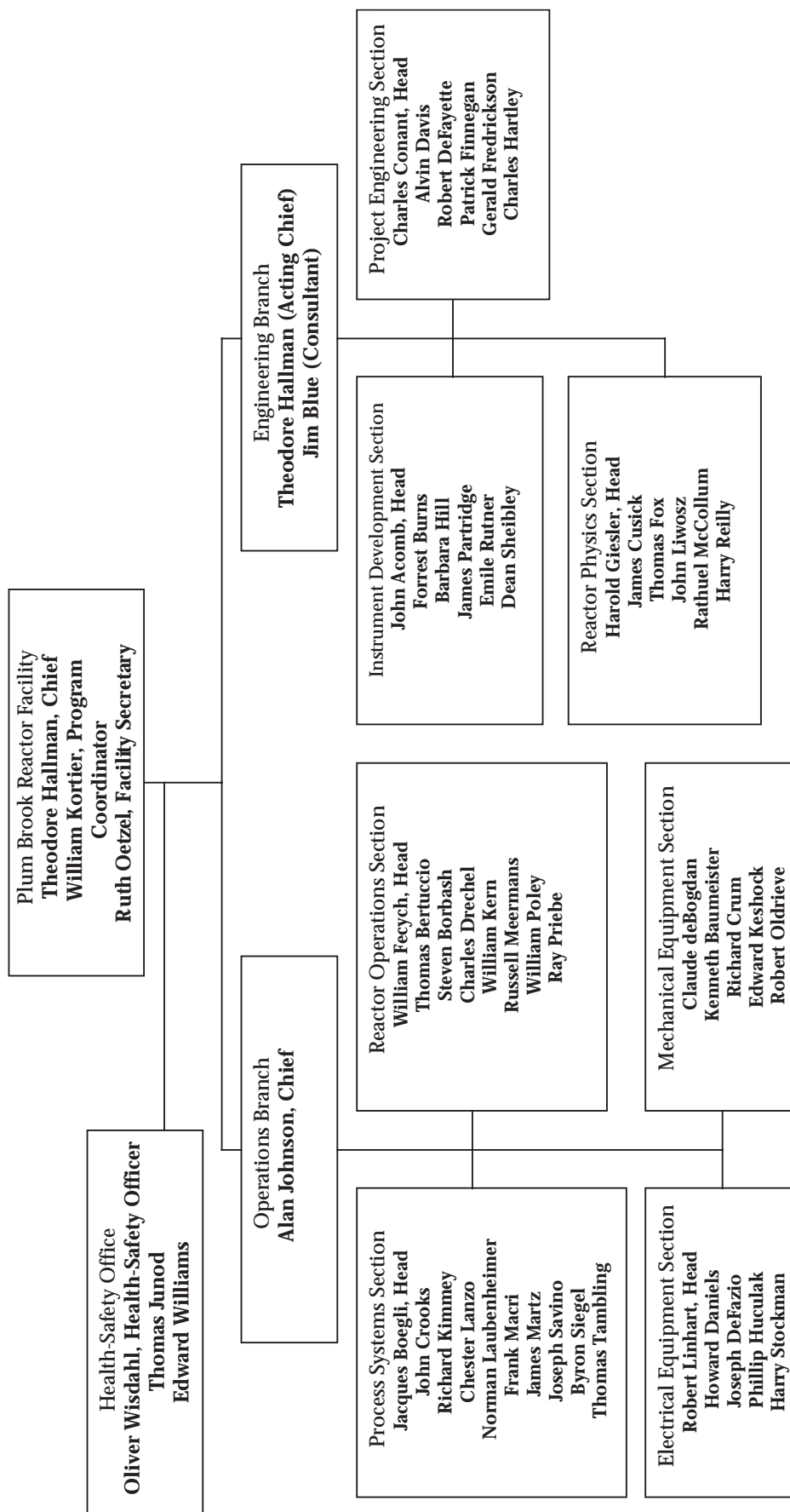
* Dotted lines are Program Direction



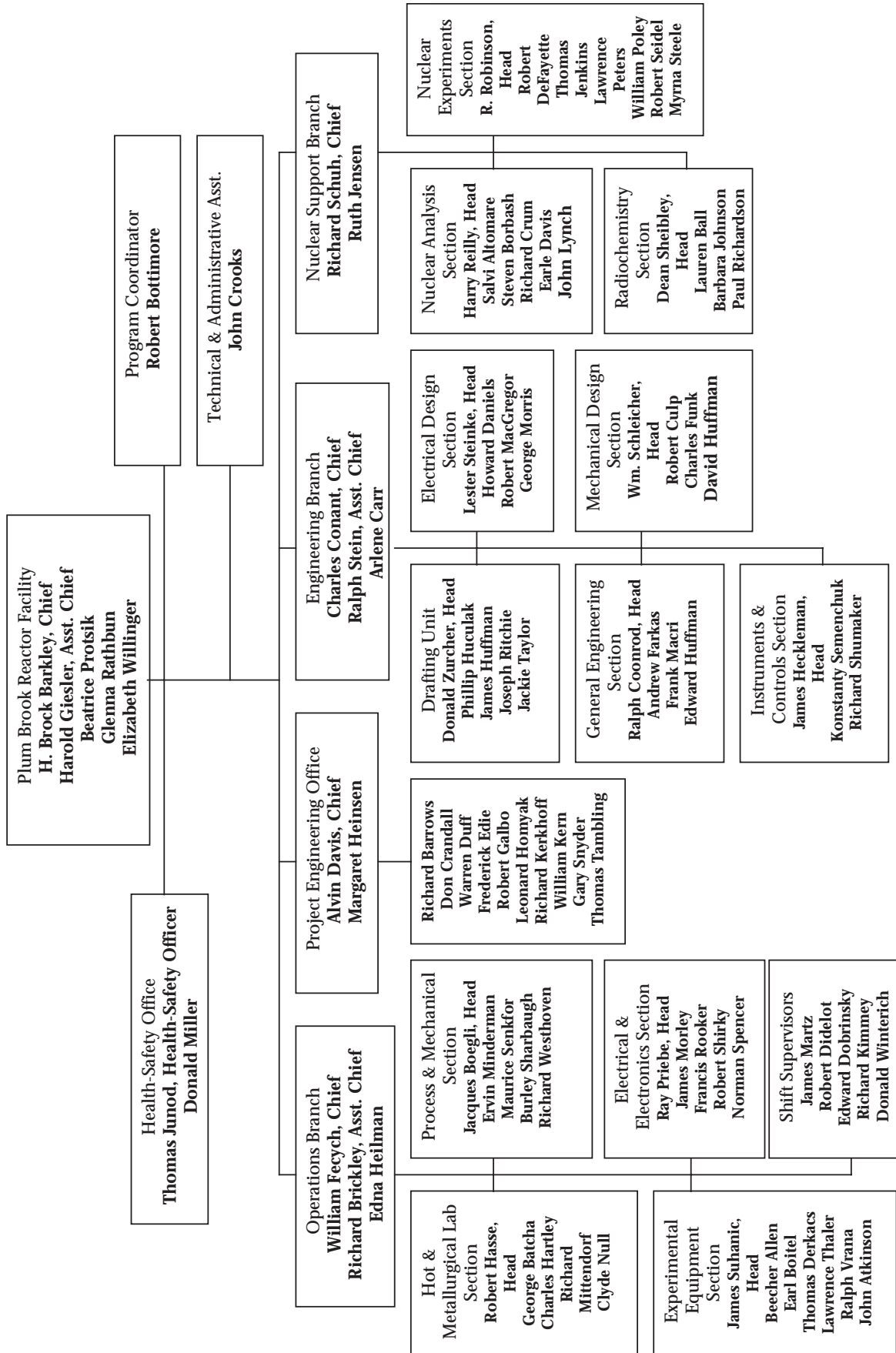
Lewis Research Center Nuclear Reactor Division (1960)



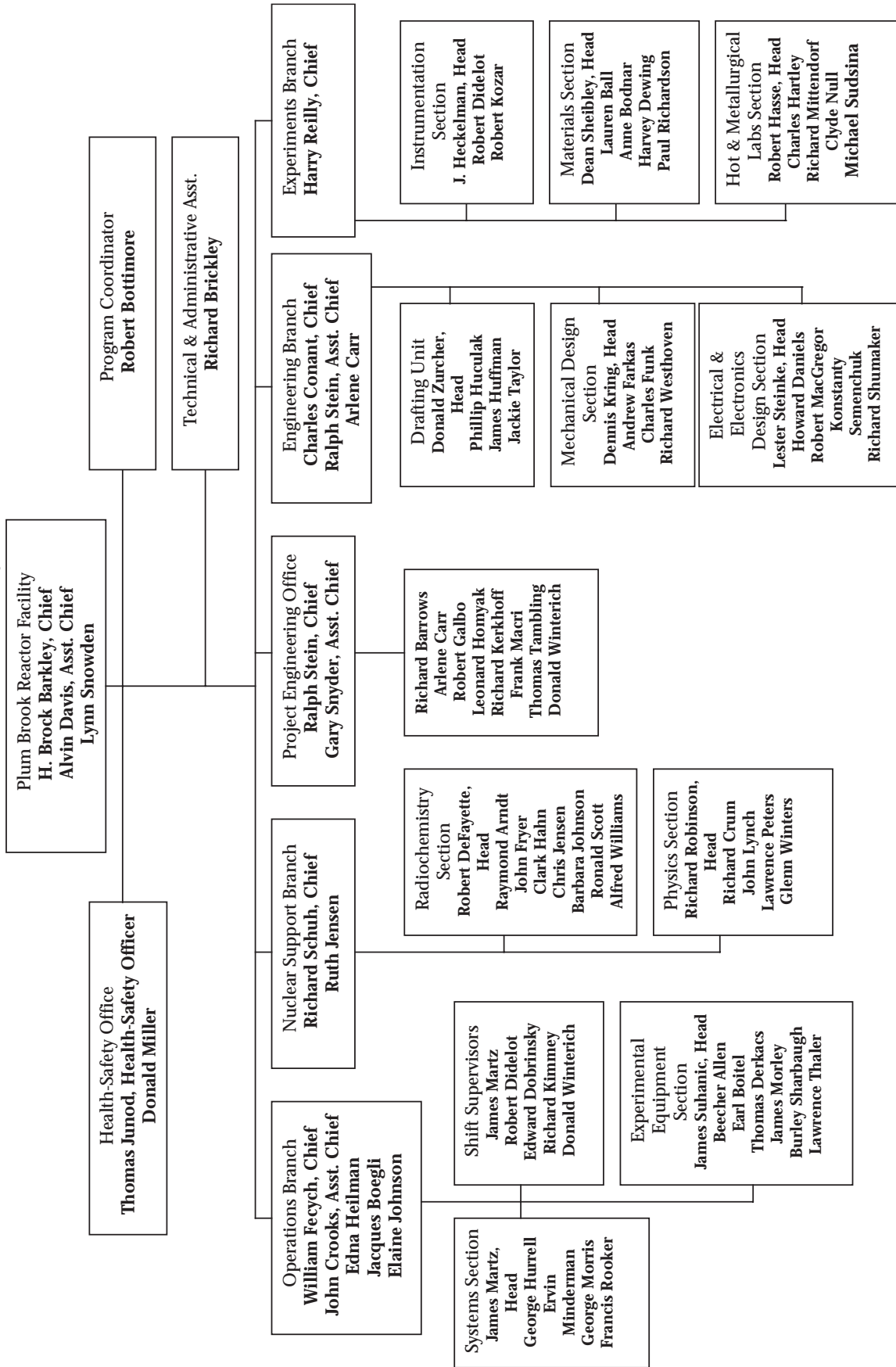
Plum Brook Reactor Facility (1959)



Plum Brook Reactor Facility (1966)



Plum Brook Reactor Facility (1971)



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Mark D. Bowles received his B.A. in Psychology (1991) and M.A. in History (1993) from the University of Akron. He earned his Ph.D. in the History of Technology and Science (1999) from Case Western Reserve University. He was the Tomash Fellow (1997–98) from the Charles Babbage Institute at the University of Minnesota. From 1996 to 2004 he was a principal at History Enterprises, Inc., where he coauthored three books with Dr. Virginia Dawson. These included *Taming Liquid Hydrogen* (2004), a history of the Centaur upper stage rocket, which the American Institute of Aeronautics honored with its 2004 History Manuscript Award. Dr. Bowles has also written *Our Healing Mission* (2003), a history of Saint Francis Hospital and Medical Center in Hartford, Connecticut. He is currently vice president and principal at Tech Pro, Inc., and he continues to write books on aviation and aerospace history. He has been married to his wife Nancy for fourteen years. They are raising their three-year-old daughter Isabelle. He can be reached at mark.bowles@case.edu.

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*"We were young and eager and we felt like we were pushing back the frontiers of science."
—A. Bert Davis, Plum Brook Reactor Facility, Chief*



NASA's Nuclear Frontier: The Plum Brook Reactor Facility

SP-2004-4533

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